Augmented reality-assisted training with selected Tai-Chi movements improves balance control and increases lower limb muscle strength in older adults: A prospective randomized trial

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ABSTRACT

Background: Tai-Chi benefits older adults by enhancing balance control and increasing the muscle strength of the lower limbs. However, a complete set of traditional Tai-Chi exercises is sometimes too difficult for beginners. We investigated whether practicing augmented reality-assisted training with selected Tai-Chi movements tailored to the practitioner's ability (selected Tai-Chi, or sTC) is as effective as performing a complete set of Tai-Chi sequences (complete traditional Tai-Chi, or tTC).

Methods: In this prospective randomized trial carried out in the Beitou District of Taipei City, Taiwan, community-dwelling adults aged $\geq$65 and without any debilitating diseases (n = 28) were included. Participants were randomly assigned to the sTC group (n = 14) or the tTC group (n = 14). Participants in the sTC group practiced selected Tai-Chi movements using the augmented reality Tai-Chi training system. Participants of the tTC group were asked to complete the 24-form Yang-style Tai-Chi following the instructions of Tai-Chi masters. Each training session lasted 30 min, with 3 sessions per week for 8 weeks. Pre- and post-intervention evaluations included functional balance tests, comprising the Berg Balance Scale (BBS), Timed Up and Go test (TUG), and Functional Reach Test (FRT), as well as muscle strength measurements of the lower extremities.

Results: Pre-intervention evaluations showed significant differences in FRT ($p = 0.034$) and left hip abductor muscle strength ($p = 0.046$) between the sTC and tTC groups. After 8 weeks of training, the BBS, TUG, and FRT scores in the sTC group showed significant improvement overall. Although all three functional balance test scores improved in the tTC group, only the improvement in BBS was statistically significant ($p = 0.001$). After 8 weeks, all muscle strength measurements increased by an average of 3.1 ± 1.0 kgw in the sTC group and 1.6 ± 0.8 kgw in the tTC group.

Conclusions: The augmented reality-assisted training with selected Tai-Chi movements, designed based on objective measurements of the practitioner's capability, improved balance control and muscle strength of lower limbs at least as effectively as the complete sequence of traditional Tai-Chi exercises.

Trial registration: This study was approved by the Institutional Review Board of National Yang-Ming University (IRB number: 1000087). Written informed consent was obtained from all participants.

Introduction

Falls are a significant threat to the quality of life in older adults, often causing a decline in self-care and in the participation in physical and social activities. Falls have multifactorial causes. Prominent intrinsic fall-risk factors are age-related decreases in

balance and strength/power performance, as well as cognitive decline.[1] In the elderly, loss of balance often results from sarcopenia and frailty,[2] and from their inability to shift their feet positions to allow adequate base of support (BOS) function.[3,4] To prevent falls, various training programs have been developed to enhance functional balance control and increase the muscle strength of the lower extremities, with some tailored specifically for the elderly.[5,6]

Tai-Chi, characterized by a sequence of gentle, low-impact, and coordinated movements, is an appropriate form of exercise for older adults because it involves minimal strain on joints and the cardiovascular system.[7] Previous studies have shown that Tai-Chi increased muscle strength in the lower extremities, and improved balance control, proprioception, and postural adaption, thereby reducing fall risk in older adults.[8–11] However, since aging is an individualized process, prescription of exercises, such as Tai-Chi, should be customized based on the health status and physical functioning of each individual. We have previously demonstrated that a set of simplified Tai-Chi exercises, consisting of only three to five movements, selected based on the subjective measurements of the practitioner's capability, could be beneficial to people with no prior experience with Tai-Chi.[12,13]

Augmented Reality (AR) is a technology that projects virtual information on the real world through image recognition, which can increase users' awareness and understanding of their surroundings.[14] In addition to games and entertainment, AR technology is currently used in medical-related fields, such as medical teaching and training, surgical simulation, and neurological rehabilitation.[15,16] In 2017, Yoo et al. used AR with electromyography (EMG) signals for neuromuscular coordination training in children with cerebral palsy. Compared to using EMG signal feedback alone, EMG combined with AR resulted in better neuromuscular effects on elbow control.[17] In the same year, Villiger et al. applied AR technology to assist in training lower limbs in patients with incomplete spinal cord injury and found significant improvements in lower limb muscle strength, balance, and functional activity.[18] Using AR with the Otago Exercise has significantly improved the strength of muscles associated with knee flexion and ankle dorsiflexion in older women, and the scores of the Morse Fall Scale among the same participants were significantly improved. There was also an improvement in the degree of asymmetry relative to the body center of gravity that provides a measure of balance.[19]

In the present study, we enhanced the participants' performance of the simplified Tai-Chi exercises by using an AR training system. We compared the beneficial effects of this AR-assisted selected Tai-Chi (sTC) intervention with the complete sequence of traditional Tai-Chi (tTC) exercises.

Methods

This study was a prospective randomized trial. Participants received baseline assessments, with follow-up after 8 weeks. The study was approved by the Institutional Review Board of the National Yang-Ming University (#1000087). Written informed consent was obtained from all participants.

Participants

As shown in Fig. 1, 28 residents of the Beitou District of Taipei City, Taiwan participated in the study. The inclusion criteria required that participants were ≥65 years of age and achieved a score of >24 on the Mini-Mental Status Examination (MMSE), indicating normal cognitive function. A certified physical therapist performed the evaluation. Exclusion criteria were disorders of the central nervous system or musculoskeletal system, including strokes, head injuries, Parkinson's Disease, fractures, or the
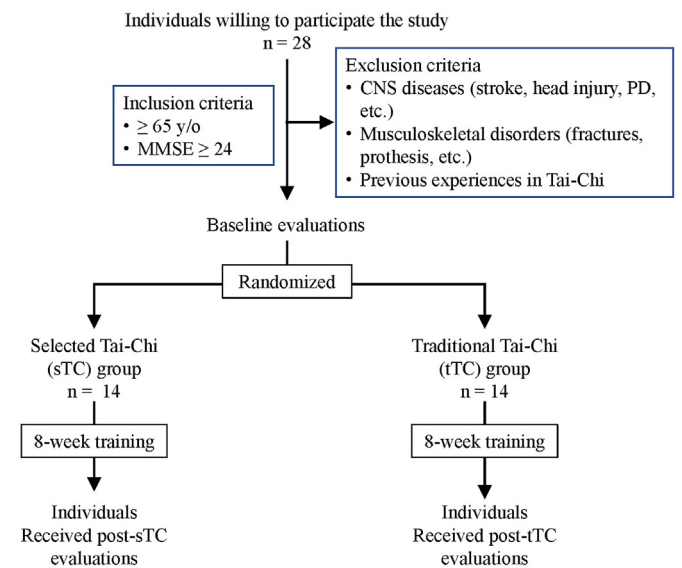

Fig. 1. Flowchart explaining the assignment of the participants to the selected Tai-Chi (sTC) group and the complete traditional Tai-Chi (tTC) group.

presence of orthopedic implants. Individuals with previous experience in Tai-Chi exercise were also excluded. After assignment to the exercise groups, all participants completed the 8 weeks of sessions as advised.

The AR-assisted training system

The AR-assisted Tai-Chi training system was developed to facilitate the practice of Tai-Chi. Microsoft Kinect system (Microsoft Corporation) was used as a body motion detector. Kinect has a three-dimension depth sensor composed of an infrared emitter and an infrared complimentary metal-oxide semi-conductor (CMOS) camera. This system can capture the movements of the entire body, as well as gestures and sounds. The Kinect software development kit was utilized to construct the digital skeleton from the spatial position of all four limbs of the performer and calculate skeletal information.[20] We used the skeletal tracking system to detect critical changes in movement of the lower limbs and collect movement data when a participant stepped forward or moved to the side. As shown in Fig. 2, a computer vision-based interaction method was employed where the skeletal data and the movements of the Tai-Chi coach were displayed to create an AR scenario for the practitioner to follow. The movements and the skeletal information of participants were also displayed. Thus, the practitioners could compare their performance of the exercises with that of the
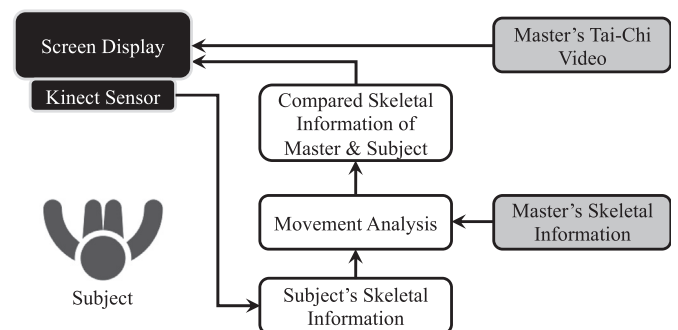

Fig. 2. Setup for the augmented reality-assisted Tai-Chi training system.

masters. The accuracy of the practitioner's movement using the skeletal information of the coach as a reference was calculated and the practitioner received real-time feedback.

Selected Tai-Chi (sTC) exercise

We monitored the base of support (BOS) of each participant by measuring the displacement of the Center of Pressure (COP) using a computerized evaluation system.[12,13] We extracted 8 simple steps from the original 24-form Yang-style Tai-Chi sequences, based on the COP analyses, for development of computer-assisted Tai-Chi exercises. Participants in the sTC group were asked to perform COP tests and were assigned one individual Tai-Chi movement at an appropriate difficulty level based on their maximum COP displacement and endurance.[13] Participants in the sTC group repeated the individually selected movement for 30 min in each training session, with three sessions per week for 8 weeks. The exercise program commenced with movements of low-difficulty, then progressed to higher difficulty as participants became adept at each movement.[13,21]

Traditional Tai-Chi (tTC) exercise

Participants of the complete traditional Tai-Chi (tTC) program learned and practiced the classical 24-form Yang-style Tai-Chi exercise under the instruction of a certified Tai-Chi master. The exercise program consisted of three sessions per week for 8 weeks and the duration of each session was 30 min. During each session, participants usually practiced a complete Yang-style Tai-Chi exercise two or three times.

Outcome measurements

Functional balance tests, including the Berg Balance Scale (BBS), Timed Up and Go test (TUG) and Functional Reach Test (FRT), as well as measurements of lower-extremity muscle strength were conducted before and after the Tai-Chi intervention. The tests and measurements were conducted by a certified physical therapist who was blinded to the sTC or tTC exercise allocation.

The BBS consisted of 14 items that evaluated the balance of each individual in sitting, standing, and transitional positions. The scores were determined using an ordinal 5-point scale with a total score ranging from 0 to 56, where higher scores indicated better balance control.[22]

The TUG is a simple test used to assess a person's mobility that requires both static and dynamic balance.[23] The test measures the time taken by a participant to stand up from a chair, walk 3 m at a comfortable speed, turn around, return to the chair, and then sit down. Three timed trials are needed to ensure performance stability in the TUG test. Mean values for three trials, with a 1-min rest between each trial, were used for analysis.

The FRT was used to assess dynamic balance. This test measures the maximal forward distance a participant could reach beyond the length of their arms. Participants were asked to stand next to a wall and reach forward as far as possible without moving their feet. The extra reaching distance was then recorded in centimeters.[24]

Lower-extremity muscle strength was measured using a hand-held isometric dynamometer, MicroFET®3 (Hoggan Health Industries). This portable digital dynamometer performs accurate, objective muscle testing and enables assessors to stabilize and assist individuals while keeping one hand free. In this study, the following 8 lower-limb muscles were bilaterally measured: hip flexor, hip extensor, hip abductor, hip adductor, knee extensor, knee flexor, ankle dorsi-flexor, and ankle plantar flexor. The participants were asked to perform maximal isometric contractions for 3 s. The

average of three measurements, at a 60-sec resting interval, were calculated and recorded.

Statistical analysis

Most of the parameters showed normal distribution and were evaluated with Shapiro-Wilk tests; only the TUG and left hip extensor muscle strength measurements of the sTC group and right ankle dorsi-flexor muscle strength measurements of tTC group showed non-normal distribution. If the parameters demonstrated normal distribution, we use a paired t-test for the within-group test and an independent t-test for the between-group test. If the parameters demonstrated non-normal distribution, the Wilcoxon test was used for the within-group test and the Mann-Whitney test was used for the between-group test. If the parameter used nonparametric statistics, it was indicated via " # " in the table. All statistical analyses were performed using PASW Statistics version 18.0 (SPSS Inc.). Statistical significance was defined as a p-value < 0.05.

Results

Demographic characteristics

A flowchart depicting the assignment of the participants to the sTC group and tTC group is shown in Fig. 1. The demographic characteristics of the participants are listed in Table 1. No significant difference was observed in the distribution of age, sex, height, and weight between the sTC and tTC groups.

Significant improvements in balance control and muscle strength were observed following the Tai-Chi interventions

The baseline and follow-up evaluation results in the sTC and tTC groups are presented in Table 2. The evaluations consisted of 3 functional balance tests, BBS, TUG, and FRT, and lower-limb muscle strength assessments. In the sTC group, BBS, TUG, and FRT scores showed significant improvement overall. The strength of each lower limb muscle also increased by an average of 3.1 ± 1.0 kgw. In the tTC group, although all three functional balance test scores improved, only the BBS improvement was statistically significant ($p = 0.001$). The muscle-strength assessments showed increases in all lower limb muscles, with an average of 1.6 ± 0.8 kgw. Improvements of the right hip flexor (RH F, $p = 0.032$), left hip flexor (LH F, $p = 0.033$), left hip abductor (LH Ab, $p = 0.001$), right ankle dorsi-flexor (RA Df, $p = 0.001$), and left ankle dorsi-flexor (LA Df, $p = 0.002$) reached statistical significance. Comparing the baseline and follow-up assessments in the sTC and tTC groups, participants in the sTC group exhibited improvements in all 19 items after the sTC intervention, while only 6 out of 19 items showed improvement after the tTC intervention.

Table 1
Demographic characteristics of participants.

	sTC Group	tTC Group	p value
Number	14	14	
Male	2	1	
Female	12	13	
Age, y/o, mean ± SD	72.2 ± 2.8	75.1 ± 5.5	0.091
Height, cm, mean ± SD	156.1 ± 6.1	154.3 ± 5.8	0.449
Weight, kg, mean ± SD	59.1 ± 8.6	58.1 ± 6.6	0.735

sTC = selected Tai-Chi; tTC = traditional Tai-Chi; SD = standard deviation.

Table 2
Baseline and follow-up evaluation results in sTC and tTC group.

	sTC Group (n = 14)			tTC Group (n = 14)		
	Baseline (mean ± SD)	Follow-up (mean ± SD)	*p* value	Baseline (mean ± SD)	Follow-up (mean ± SD)	*p* value
Functional Balance						
BBS	50.3 ± 2.1	54.0 ± 1.1	<0.001*	49.2 ± 4.5	51.1 ± 4.7	0.001*
TUG	8.7 ± 0.7	6.9 ± 0.9	0.001#*	9.0 ± 1.8	8.4 ± 1.6	0.115
FRT	28.7 ± 4.2	32.5 ± 4.1	<0.001*	24.3 ± 5.6	24.8 ± 3.8	0.766
Muscle Strength						
RH F	17.7 ± 6.1	22.2 ± 7.5	0.001*	16.6 ± 3.9	18.5 ± 3.1	0.032*
LH F	17.1 ± 6.2	21.7 ± 7.7	0.001*	15.4 ± 4.3	17.7 ± 3.4	0.033*
RH E	17.1 ± 5.1	20.8 ± 7.4	0.007*	16.4 ± 2.9	18.2 ± 3.8	0.083
LH E	17.8 ± 5.8	21.5 ± 8.6	0.001#*	16.2 ± 2.9	17.1 ± 3.4	0.310
RH Ab	12.9 ± 3.4	16.8 ± 5.9	0.003*	15.7 ± 3.4	16.8 ± 2.6	0.276
LH Ab	12.5 ± 3.2	15.7 ± 5.5	0.002*	12.3 ± 2.0	15.8 ± 2.9	0.001*
RH Ad	11.6 ± 3.2	14.3 ± 4.8	0.005*	11.1 ± 2.1	12.9 ± 2.9	0.050
LH Ad	10.7 ± 3.2	13.9 ± 4.7	0.007*	12.1 ± 2.8	13.4 ± 2.6	0.121
RK F	11.7 ± 3.7	12.7 ± 4.0	0.010*	13.3 ± 2.6	14.1 ± 2.5	0.323
LK F	11.0 ± 3.7	13.1 ± 4.9	0.009*	12.8 ± 2.6	13.8 ± 2.9	0.226
RK E	19.1 ± 4.2	21.4 ± 5.8	0.019*	18.2 ± 3.5	18.9 ± 4.6	0.418
LK E	18.1 ± 4.0	21.2 ± 5.6	<0.001*	16.9 ± 2.4	17.8 ± 4.3	0.424
RA Df	13.3 ± 3.9	15.4 ± 5.0	0.003*	11.1 ± 2.3	13.9 ± 2.7	0.001#*
LA Df	12.5 ± 3.7	15.1 ± 4.7	<0.001*	11.4 ± 2.5	14.0 ± 2.9	0.002*
RA Pf	18.3 ± 4.1	22.8 ± 8.3	0.015*	17.6 ± 2.3	19.3 ± 3.6	0.128
LA Pf	18.6 ± 3.9	21.7 ± 6.7	0.010*	16.7 ± 2.8	17.3 ± 4.0	0.445

nonparametric statistics; *p < 0.05; sTC = selected Tai-Chi; tTC = traditional Tai-Chi; SD = standard deviation; BBS = Berg Balance Scale; TUG = Timed Up and Go test; FRT = Functional Reach Test; RH = righ hip; F = flexor; LH = left hip; E = extensor; Ab = abductor; Ad = adductor; RK = right knee; LK = left knee; RA = right ankle; Df = dorsi-flexor; LA = left ankle; Pf = plantar-flexor.

Beneficial effects of the AR-assisted selected Tai-Chi program were comparable to the complete Tai-Chi sequence

Comparisons of the functional balance tests and muscle strength measurements between the sTC and tTC groups are shown in Table 3. Pre-intervention evaluations showed significant differences in FRT (p = 0.034) and RH Ab (p = 0.046) between the sTC and tTC groups and post-intervention evaluations showed significant differences in BBS (*p* = 0.044), TUG (*p* = 0.015), and FRT (*p* < 0.001) between groups.

Discussion

The Kinect depth sensor and skeleton tracking system senses the body movement of the participant without using other input devices and limits the disturbance of movement, which is especially important for elderly people.

The measurements used in the current study were not tests specific to Tai-Chi, however, assessments such as BBS[25,26], TUG[27], and lower limb muscle strength[28-30] have been widely used in the other Tai-Chi studies. In this study, we found that both sTC and tTC

Table 3
Baseline and follow-up evaluation results between sTC and tTC groups.

	Baseline			Follow-up		
	sTC group (mean ± SD)	tTC group (mean ± SD)	*p* value	sTC group (mean ± SD)	tTC group (mean ± SD)	*p* value
Functional Balance						
BBS	50.3 ± 2.1	49.2 ± 4.5	0.444	54.0 ± 1.1	51.1 ± 4.7	0.044*
TUG	8.7 ± 0.7	9.0 ± 1.8	0.890#	6.9 ± 0.9	8.4 ± 1.6	0.015#*
FRT	28.7 ± 4.2	24.3 ± 5.6	0.034*	32.5 ± 4.1	24.8 ± 3.8	<0.001*
Muscle Strength						
RH F	17.7 ± 6.1	16.6 ± 3.9	0.594	22.2 ± 7.5	18.5 ± 3.1	0.119
LH F	17.1 ± 6.2	15.4 ± 4.3	0.413	21.7 ± 7.7	17.7 ± 3.4	0.094
RH E	17.1 ± 5.1	16.4 ± 2.9	0.673	20.8 ± 7.4	18.2 ± 3.8	0.265
LH E	17.8 ± 5.8	16.2 ± 2.9	0.890#	21.5 ± 8.6	17.1 ± 3.4	0.301#
RH Ab	12.9 ± 3.4	15.7 ± 3.4	0.046*	16.8 ± 5.9	16.8 ± 2.6	0.990
LH Ab	12.5 ± 3.2	12.3 ± 2.0	0.841	15.7 ± 5.5	15.8 ± 2.9	0.936
RH Ad	11.6 ± 3.2	11.1 ± 2.1	0.645	14.3 ± 4.8	12.9 ± 2.9	0.372
LH Ad	10.7 ± 3.2	12.1 ± 2.8	0.278	13.9 ± 4.7	13.4 ± 2.6	0.759
RK F	11.7 ± 3.7	13.3 ± 2.6	0.207	12.7 ± 4.0	14.1 ± 2.5	0.320
LK F	11.0 ± 3.7	12.8 ± 2.6	0.151	13.1 ± 4.9	13.8 ± 2.9	0.672
RK E	19.1 ± 4.2	18.2 ± 3.5	0.551	21.4 ± 5.8	18.9 ± 4.6	0.234
LK E	18.1 ± 4.0	16.9 ± 2.4	0.382	21.2 ± 5.6	17.8 ± 4.3	0.087
RA Df	13.3 ± 3.9	11.1 ± 2.3	0.089#	15.4 ± 5.0	13.9 ± 2.7	0.476#
LA Df	12.5 ± 3.7	11.4 ± 2.5	0.416	15.1 ± 4.7	14.0 ± 2.9	0.458
RA Pf	18.3 ± 4.1	17.6 ± 2.3	0.587	22.8 ± 8.3	19.3 ± 3.6	0.173
LA Pf	18.6 ± 3.9	16.7 ± 2.8	0.160	21.7 ± 6.7	17.3 ± 4.0	0.054

nonparametric statistics; *p < 0.05; sTC = selected Tai-Chi; tTC = traditional Tai-Chi; SD = standard deviation; BBS = Berg Balance Scale; TUG = Timed Up and Go test; FRT = Functional Reach Test; RH = righ hip; F = flexor; LH = left hip; E = extensor; Ab = abductor; Ad = adductor; RK = right knee; LK = left knee; RA = right ankle; Df = dorsi-flexor; LA = left ankle; Pf = plantar-flexor.

training could improve a practitioner's balance control and increase lower limb muscle strength after an 8-week intervention. Furthermore, the added benefits of performing simplified and personalized Tai-Chi exercises were substantial compared to the complete set of traditional Tai-Chi sequences, even if not to the level of statistical significance. An explanation of these results might be that the traditional Tai-Chi sequences contained movements that were too difficult for elderly practitioners. It has been shown that the amplitude of weight-shifting estimated by the degree of COP displacements differed among Tai-Chi movements.[31] Practitioners with limited ability to voluntarily shift their weight in different spatial directions and to briefly maintain stability in different positions may encounter difficulty in conducting the movements. Thus, not all older individuals can complete the full set of exercises included in a traditional Tai-Chi program. We noted that the participants in the tTC group often omitted or skipped complicated movements or performed the steps at their own will. Therefore, older participants may require special considerations when a Tai-Chi exercise program is developed for them.[32]

Many researchers have tried to simplify Tai-Chi programs.[33–36] However, most of the simplified exercises were designed primarily based on the advice of experts rather than on the practitioner's abilities, and the training course was typically conducted at a predetermined level of difficulty. With such a design, the only option for many participants would be to give up when encountering movements that were beyond their capabilities. For example, the one-legged station step of the traditional Tai Chi exercise was too difficult for most elderly practitioners, yet could be readily accomplished by some older individuals. Therefore, simplified Tai-Chi exercises need to be customized to achieve optimal outcomes. We previously reported the development of personalized Tai-Chi exercise programs for older adults based on the practitioners' COP displacement values.[12,13] Therefore, the individual Tai-Chi movements assigned to the practitioner were not only feasible but were also at an appropriate level of difficulty. In the present study, we have developed this sTC program further by incorporating virtual reality (VR)-augmented or AR-assisted Tai-Chi training systems[37] in the exercise intervention protocols. The trainees could perform individual Tai-Chi movements at a high level of accuracy by comparing their own skeletal information with that of the Tai-Chi master, thereby achieving increased optimal training goals set by the trainer.

In the present study, participants in the sTC group were asked to practice only one movement repeatedly in each session. The movement was assigned according to the practitioner's balance control as assessed through COP measurements. The training was also designed to be progressive, with the practitioner continuously challenged in a gradual manner. When the original movement was learned and mastered, the trainer assigned another Tai-Chi movement that required an increased COP displacement or was at a higher difficulty level. The superior training results observed in the sTC group might have been attributable to the individually tailored Tai-Chi movements and the progressive intensity and complexity of the practice.

Tai-Chi exercises require the coordination of breathing and motor functions. It has been reported that Tai-Chi movements stimulated the part of the brain that governs balance, thereby increasing overall steadiness.[38–41] Previous studies have also shown that a relatively long period of practice, typically from 12 to 48 weeks, was required for older practitioners to benefit from Tai-Chi exercises.[8,38,42,43] In our study, we demonstrated that merely 8 weeks of intervention with simplified and personalized Tai-Chi training could provide significant benefit, comparable to that achieved with extended periods of Tai-Chi practice. Thus, simplified and personalized Tai-Chi exercises are particularly useful for Tai-Chi beginners and provide substantial benefit for those who

cannot learn and practice the complete Tai-Chi sequence, such as frail or disabled elderly individuals and those who cannot comprehend or memorize the full Tai-Chi sequence. Moreover, the AR-assisted Tai-Chi training program developed in the present study can serve as an operative assistive methodology to help the practitioner exercise without the physical presence of a coach, improve exercise adherence, achieve the trainer's goals, and maximize the training outcome. The results of our study suggest that performing selected Tai-Chi exercises was at least as useful and, for certain practitioners, even more beneficial than conducting the full sets of traditional Tai-Chi exercises.

The primary limitations of this study are the relatively small number of participants and imbalance among the sexes. There were more female individuals recruited than males. It is not possible to separate the statistics based on sex. Thus, the conclusions from this study should be made with caution, with the caveat that the evidence supports the benefit of sTC only for women. The included participants had prior exercise habits, but none had previous experience with Tai-Chi. The frequency of exercise of the participants was generally 2–3 times per week and types of exercise included walking, swimming, and social dance. The study did not ask participants to stop their current exercise during the intervention. In addition, the functional assessments of this study focused mainly on balance control and muscle strength of the lower limbs, without considering other beneficial effects typically associated with the complete set of traditional Tai-Chi sequences. It would be informative to conduct a follow-up survey to compare differences in cognition, adherence rate, or personal mental health status between the tTC and sTC group participants in the future.

Conclusions

We found that simplified and personalized Tai-Chi training, designed based on objective measurements of the practitioner's capability and conducted under the guidance of a VR-augmented training system with progressive intensity and complexity, could achieve training goals more readily than use of traditional full-course Tai-Chi, especially for beginners or laypersons not familiar with this type of exercise.

Declaration of competing interest

The authors declare that there is no conflict of interest.

CRediT authorship contribution statement

Po-Jung Chen: Conceptualization, Methodology, Software, Investigation, Data curation, Writing - original draft. **I-Wen Penn:** Conceptualization, Formal analysis, Resources, Writing - review & editing. **Shun-Hwa Wei:** Methodology, Supervision. **Long-Ren Chuang:** Methodology, Resources, Supervision. **Wen-Hsu Sung:** Conceptualization, Methodology, Software, Validation, Visualization, Supervision, Project administration.

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