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Research Article

Evaluation of Training Effects Between Tai Chi Robotic and Tai Chi Master on Improving Balance and Muscle Strength in Hong Kong Chinese Older Adults

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Abstract

Objectives: Falls are a prevalent concern among elderly with research showing that Tai Chi is effective in improving balance. This study aimed to investigate the effectiveness of the recently developed Tai Chi Robotic Machine on improving balance and muscle strength in Hong Kong Chinese older adults compared to Tai Chi Master. **Methods:** 94 community-dwelling Hong Kong Chinese older adults were recruited territory-wide and randomly assigned to the Tai Chi Robotic (TR) Group (13 males and 42 females, aged 68.66 ± 5.37) and Tai Chi Master (TM) Group (7 males and 32 females, aged 69.15 ± 6.70) for 12 sessions of Tai Chi training (2 sessions per week for 6 weeks). Subjects' demographic profiles, fall history, Aspire Fall Risk Score (FRS), Berg Balance Scale (BBS), Single-Leg-Stand (SLS), self-reported perceived balance, handgrip strength, Short Form 12 Physical and Mental Component Summary (SF-12 PCS & MCS) were assessed at baseline, post-intervention and 1-month follow-up intervals. **Results:** Post-intervention improvements in Aspire FRS (from 6.69 ± 2.03 to 7.87 ± 1.09 in TR Group; from 6.46 ± 2.21 to 7.54 ± 1.52 in TM Group, $p \leq 0.01$); BBS (from 49.51 ± 6.40 to 53.62 ± 3.12 in TR Group; from 50.67 ± 5.85 to 52.54 ± 4.53 in TM Group, $p \leq 0.01$); self-reported perceived balance (from 2.20 ± 0.83 to 2.96 ± 0.69 in TR Group; 1.97 ± 0.58 to 2.59 ± 0.64 in TM Group, $p \leq 0.01$); SLS (from 23.80 ± 36.56 to 32.33 ± 2.76 in TM Group, $p \leq 0.05$). At 1-month follow-up, both TR and TM Groups maintained the benefits in balance. **Discussion:** Both TM and TR Groups showed similar training effects in improving balance and muscle strength among Hong Kong Chinese older adults. This highlights that the Tai Chi Robotic Machine can be a scalable and accessible modality for fall prevention and community-based rehabilitation in aging populations. **Conclusion:** The TM and TR Groups' comparable effectiveness proved that the Tai Chi Robotic Machine could be an alternative for traditional Tai Chi Master.

Background

Hong Kong is currently experiencing a significant demographic shift towards an aging population. The United Nations (2023) estimated that Hong Kong ranks second globally in life expectancy, a phenomenon attributed to its robust healthcare infrastructure and improved living standard [1]. While this reflects advancements in public health, it also contributes to a pronounced transition towards aging. Data from the Census and Statistics Department of Hong Kong (2023) project a significant shift in population structure, with the median age rising from 47.3 in 2021 to 55.5 by 2046. Concurrently, the proportion of individuals aged 65 and above is expected to increase markedly from 20% to 36%, representing a 1.8-fold rise over the same period [2].

Age-related physiological changes, including decreased metabolic rate and declining sex hormone levels are known to reduce bone mineral density, thereby increasing the risk of development of osteoporosis. These factors, combined with higher rates of falls among older adults, contribute substantially to the incidence of fragility fractures, which is one of the leading causes of elderly hospitalization in Hong Kong. According to Osipov & Christiansen (2021), individuals who suffer an initial fracture are at elevated risk for subsequent fractures [3]. As such, fall prevention interventions, particularly those that improve balance and muscular strength are of utmost importance.

Numerous strategies exist for fall prevention, among which Tai Chi emerged as an effective modality. This traditional, low-impact exercise is widely favoured among older adults and has been demonstrated to enhance muscular strength, proprioception and endurance. Evidence supports Tai Chi's efficacy in fall prevention and balance enhancement among elderly populations [4-6]. The traditional Tai Chi training is typically conducted in group sessions led by a Tai Chi Master, in which logistical challenges such as time constraints, resource limitations and space availability may hinder the consistent implementation of such programs in community settings across Hong Kong.

Integrating modern technologies into Tai Chi practice may prove to be a viable alternative. This can be exemplified by the introduction of the Tai Chi Robotic Machine, a Geron-technology product recently introduced in Hong Kong. With an approved DEKRA (Report No. 6106609.51QS), this study aimed to evaluate and compare the training effects of the Tai Chi Robotic Machine and traditional Tai Chi Master in improving balance and muscle strength among community-dwelling Hong Kong Chinese older adults in Hong Kong.

Methods

Ethical Approval

This study was approved by the Tung Wah College Research Ethics Committee (Ref. No.: REC2023170) and was conducted in compliance with the Declaration of Helsinki. It was carried out at Tung Wah College Ma Kam Chan Memorial Building, Hong Kong from 2024 to 2025. Prior to the study's enrolment, a written consent form that outlined the study's objectives, nature and purpose was provided to and obtained from all subjects. All data and personal details gathered were treated confidentially to uphold privacy standards.

Study Design

This study was a cohort study consisting of two groups, the Tai Chi Robotic (TR) group and the Tai Chi Master (TM) group. Both groups received 12 sessions of Tai Chi training, supplemented with educational leaflets on fall prevention. Assessments were conducted at three time points, baseline (pre-intervention), post-intervention (after finishing 12 sessions) and 1-month follow-up to evaluate the sustainability of the training effects.

Inclusion and Exclusion Criteria

Subjects recruited based on the following inclusion and exclusion criteria:

Inclusion Criteria:

1. Aged 60 or above
2. Community-dwelling
3. Able to walk unaided and independently
4. Able to attend Tung Wah College for assessment and training
5. Able to complete the written informed consent form

Exclusion Criteria:

1. Diagnosed with severe musculoskeletal, cardiovascular, neurological or psychiatric conditions
2. Received bilateral hip replacement or spinal surgery
3. Diagnosed with malignancy
4. Have previously received Tai Chi training
5. Currently undergoing other balance training programs

Convenient sampling through online advertisement via social media and poster distribution in community centres and residential areas territory-wide across Hong Kong was used to recruit subjects based on the inclusion and exclusion criteria. The randomization process was then performed by an external assistant not involved in the study with group allocation concealed to ensure anonymity.

Interventions

In the TR group, subjects received training via the Tai Chi Robotic Machine, which provides 8 Chen-style Tai Chi movements based on the techniques of renowned Tai Chi Master, Master Chow. The movement sequences include Horizontal Push, Outer Push, Clockwise Oval, Anti-clockwise Oval, Forward Rollback, Backwards Rollback, Large Circle Spiralling and Small Circle Spiralling. Each movement was performed for 3 minutes, with a 30-second rest period between movements. To perform Tai Chi through the Robotic Machine, subjects place their hands on the machine's ball-shaped handle, which will guide their upper limb movements and weight-shifting, providing directional guidance to learn the complex three-dimensional Tai Chi movements. Training was conducted twice weekly, each session lasting 30 minutes, for a total of 12 sessions.

For the TM group, Tai Chi training was held in a group class led by Master Chow, the same Chen-style Tai Chi Master that the movement styles of the Robotic Machine were based on. The subjects were divided into 2 classes, each consisting of 20 subjects. The movement forms taught in the TM group were the same Chen-style Tai Chi as the TR group, but included additional stepping and turning components, reflecting traditional instructional variations. Training was conducted twice weekly, each session lasting 60 minutes, for a total of 12 sessions.

Outcome Measures

Subjects' demographic data and outcomes assessment were recorded at baseline, after 12 sessions of Tai Chi and 1-month post-intervention. All measurements were recorded by the same investigators to maintain accuracy and consistency. The following outcome measures were recorded:

1. Aspire Fall Risk Score (FRS) using the Aspire motion sensor belt and the Aspire app. It evaluates fall risk through three key tests: the Romberg test, the sit-to-stand test and the 6-meter walk test. The score reflects the steadiness, coordination, lower limb strength and functional efficiency of subjects [7].

2. Berg Balance Scale (BBS) consists of 14 activities focusing on daily balancing tasks. The scale is used to evaluate the balancing ability and potential fall risk of participants as they navigate through different balancing activities [8].

3. Single Leg Stance (SLS) assesses static postural and balance control. It is a widely used fall risk predictor to quantify balance status [9].

4. Self-reported perceived balance serves as a subjective measurement to evaluate the weight-bearing and weight-shifting status of subjects, consisting of 4 self-reported gradings, including poor, fair, satisfactory and good on a scale from 1 to 4.

5. Handgrip strength assesses upper limb strength using the handheld Jamar dynamometer. It is also a predictor of future fall risks, being significantly associated with lower limb weakness, frailty, sarcopenia and reduced physical performance [10].

6. 12-Item Short Form Survey (SF-12) is a self-reported quality of life outcome measure that assesses the impact of health on an individual's everyday life. It contains both physical and mental component score summaries which provide a comprehensive evaluation of an individual's perceived overall physical and mental health [11].

Sample Size Calculation and Statistical Analysis

The sample size for this study was determined using the formula $N = [(Z\text{-score})^2 \times p \times (1 - p)] / (\text{margin of error})^2 \times DEFF$. Taking reference to prior studies evaluating Tai Chi's effects on balance and fall risk in older adults, an estimated effect size of 0.25 (moderate effect) was assumed [12]. With a tolerated margin of error of 5%, a confidence level of 95% ($Z = 1.96$), and DEFF of 1.2 to account for variability in training settings and participant characteristics, the minimum required sample size was calculated to be 96. To accommodate for potential dropouts the target sample size was increased by 5%, with the total effective sample size required being 101. A total of 103 subjects were recruited with 94 subjects completing the study, which was 94% of the expected effective sample size. Statistical data analysis was conducted using SPSS version 27. Statistical significance was set at $p < 0.05$.

Results

103 subjects were recruited at the start of the study with 2 individuals being excluded prior to randomization due to the presence of cardiovascular diseases. The 101 eligible subjects were randomly allocated to either the TM or the TR group. During the intervention period, 7 participants withdrew from the study: 5 from the TR group and 2 from the TM group due to time availability and transportation issues. Ultimately, a total of 94 subjects completed the full intervention and follow-up assessments (n=39 in TM group; n=55 in TR group) (Figure 1).

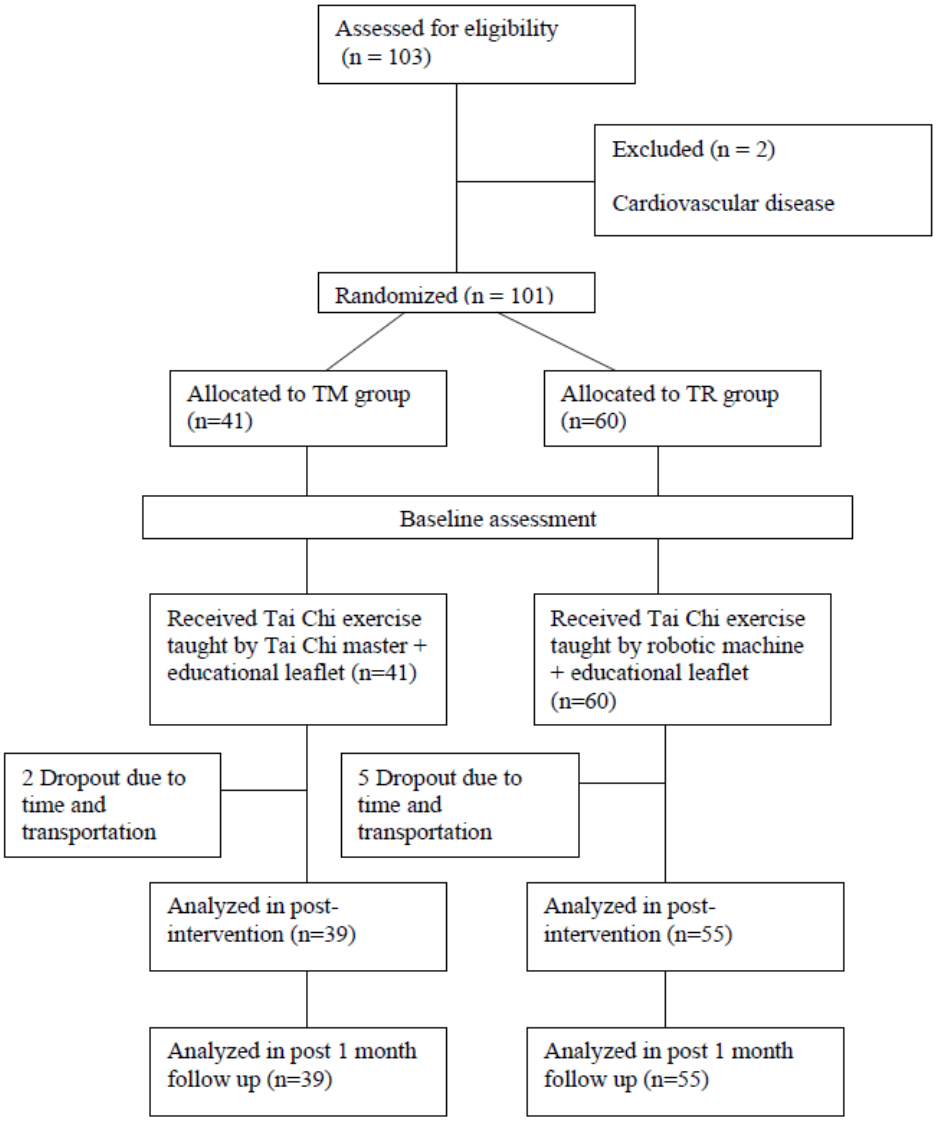

Figure 1: Consort Diagram of the Study.

Demographics

Descriptive data analysis for demographics information, number of falls in the past 12 months and number of comorbidities was conducted. The mean age of the TM group was 69.15 ± 6.70 and the TR group was 68.66 ± 5.37. The male-to-female ratios in the TM group and TR group are approximately 0.2:1 and 0.3:1 respectively. Subjects in the TM group experienced a mean number of falls of 0.44 ± 0.75 in the past 12 months, while the number of falls in the TR group was 0.35 ± 0.58. The mean number of comorbidities was 1.38 ± 1.09 in the TM group and 1.58 ± 1.61 in the TR group (Table 1).

	Tai Chi Master Group (n=39)	Tai Chi Robotic Group (n=55)
Age (years)	69.15 ± 6.70	68.66 ± 5.37
Male	7 (18%)	13 (24%)
Female	32 (82%)	42 (76%)
Height (cm)	158.49 ± 8.06	158.33 ± 8.17
Weight (kg)	57.20 ± 13.24	55.63 ± 9.48
Number of falls in the past 12 months (times)	0.44 ± 0.75	0.35 ± 0.58
Number of comorbidity (s)	1.38 ± 1.09	1.58 ± 1.61
Note: The values are presented as mean ± SD or number (%)		

Table 1: Demographics of Subjects.

Aspire Fall Risk Score

The Aspire Fall Risk Score in both the TM group (from 6.46 ± 2.21 to 7.54 ± 1.52) and TR group (from 6.69 ± 2.03 to 7.87 ± 1.09) demonstrated significant improvements from pre-intervention to post-intervention ($p<0.001$). No significant difference was found between the TM and TR groups at post-intervention and 1-month follow-up, suggesting that both interventions were similarly effective (refer Table 2). Both groups demonstrated an upward trend which plateaued at post-intervention and sustained in 1-month follow-up, reflecting prolonged training effects (Figure 2).

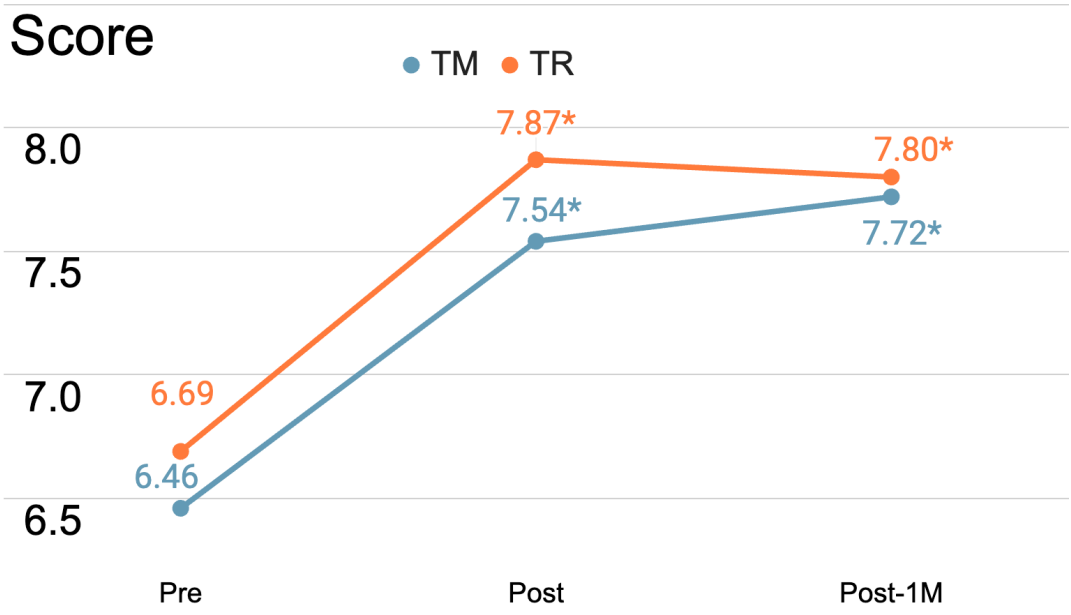

Figure 2: Line Graph of Mean Aspire Fall Risk Score.

Berg Balance Scale

The Berg Balance Scale in both the TM group (from 50.67 ± 5.85 to 52.54 ± 4.53) and TR group (from 49.51 ± 6.40 to 53.62 ± 3.12) showed significant improvements from pre-intervention to post-intervention ($p<0.001$). The magnitude of TR group's improvement also appeared more than TM group. There was no significant difference between TR and TM in post-intervention, showing similar effectiveness in the two groups (refer Table 2). Both groups demonstrated an upward trend which plateaued at post-intervention and sustained in 1-month follow-up, showing that the training effects were maintained (Figure 3).

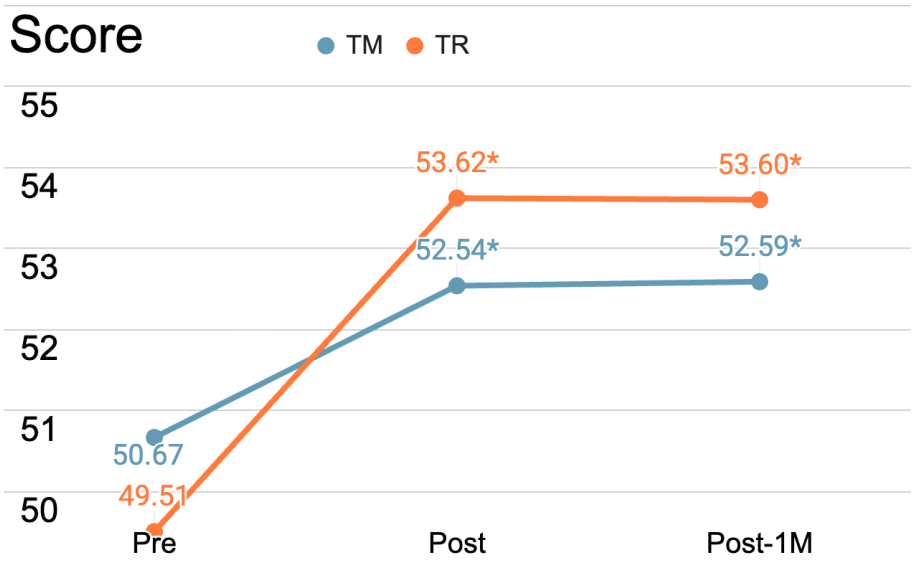

Figure 3: Line Graph of Mean Berg Balance Scale Score.

Single Leg Stance

The TM group demonstrated a significant improvement of single leg stance time from pre-assessment to post-assessment (from 23.80 ± 36.56 to 32.33 ± 2.76, $p<0.05$), but the SLS time decreased in the post 1-month assessment (from 32.33 ± 2.76 to 29.09 ± 3.67), although it still improved compared to the baseline. As for the TR group, despite not showing statistically significant improvement, the SLS time showed an improving trend that continued from baseline to post-assessment, and sustaining till post 1-month assessment (from 21.32 ± 30.78 to 25.84 ± 3.09) (Table 2).

Self-Reported Perceived Balance

The self-reported perceived balance in the TM group (from 1.97 ± 0.58 to 2.59 ± 0.64) and TR group (from 2.20 ± 0.83 to 2.96 ± 0.69) both showed significant improvements from pre-intervention to post-intervention ($p<0.001$). The two groups had comparable effectiveness with no significant difference between both groups. The trend of both the TM group and TR group was also increasing throughout pre-intervention to the 1-month follow-up assessment, reflecting a sustained training effect on the subjects' self-reported perceived balance (Table 2).

Handgrip Strength

Both the TM group (from 22.23 ± 7.13 to 23.00 ± 7.22) and TR group (from 22.71 ± 8.73 to 22.84 ± 8.73) showed a slight upward trend in handgrip strength from pre-intervention to post-intervention, which sustained at the 1-month follow-up period. The improvement of the TM group was also slightly more than that of the TR group. The differences between the two groups were not statistically significant at any time point, as analysis showed no significant changes in handgrip strength over time ($p>0.05$) (Table 2).

SF-12 PCS

The SF-12 PCS scores in both the TM group (from 45.83 ± 7.39 to 49.11 ± 0.841) and TR group (from 48.20 ± 7.39 to 49.82 ± 0.697) showed an increasing trend from pre-intervention to post-intervention, also sustaining to the 1-month follow-up assessment. While the PCS scores generally improved over time compared to baseline, the increase did not reach statistical significance ($p>0.05$). This pattern of improvement also did not significantly differ across the TM and TR groups (Table 2).

SF-12 MCS

The TM group (from 50.64 ± 9.74 to 52.27 ± 8.12) and TR group (from 51.76 ± 8.05 to 53.40 ± 6.69) both showed an improving trend from pre-intervention to post-intervention for the SF-12 MCS score. The increase sustained till the 1-month follow-up period in the TM group (from 52.27 ± 8.12 to 52.91 ± 7.99), while the TR group (from 53.40 ± 6.69 to 52.98 ± 7.31) showed a slight decrease in MCS score during the same period. No statistically significant differences were observed between the two groups at any time point, and the within-group changes were also not significant ($p>0.05$) (Table 2).

		Tai Chi Master Group (n=39)	Tai Chi Robotic Group (n=55)	Between group p-value
Aspire Fall Risk Score	Pre	6.46 ± 2.21	6.69 ± 2.03	0.604
	Post	7.54 ± 1.52	7.87 ± 1.09	0.217
	Post-1M	7.72 ± 1.38	7.80 ± 1.13	0.752
	Within group p-value			
	Pre vs Post	<0.001*	<0.001*	/
	Post vs post-1M	0.213	0.468	/
	Overall	<0.001*	<0.001*	/
Berg Balance Scale	Pre	50.67 ± 5.85	49.51 ± 6.40	0.373
	Post	52.54 ± 4.53	53.62 ± 3.12	0.174
	Post-1M	52.59 ± 4.46	53.60 ± 3.42	0.217
	Within group p-value			
	Pre vs Post	<0.001*	<0.001*	/
	Post vs post-1M	0.623	0.927	/
	Overall	<0.001*	<0.001*	/
Single Leg Stance (secs)	Pre	23.80 ± 36.56	21.32 ± 30.78	0.724
	Post	32.33 ± 2.76	25.64 ± 2.33	0.256
	Post-1M	29.09 ± 3.67	25.84 ± 3.09	0.473
	Within group p-value			
	Pre vs Post	<0.001*	<0.022*	/
	Post vs post-1M	0.272	0.96	/
	Overall	0.021*	0.065	/
Self-Reported Perceived Balance	Pre	1.97 ± 0.58	2.20 ± 0.83	0.146
	Post	2.59 ± 0.64	2.96 ± 0.69	0.01
	Post-1M	2.62 ± 0.63	3.02 ± 0.71	0.006
	Within group p-value			
	Pre vs Post	<0.001*	<0.001*	/
	Post vs post-1M	0.57	0.182	/
	Overall	<0.001*	<0.001*	/

Handgrip Strength (kgf)	Pre	22.23 ± 7.13	22.71 ± 8.73	0.779
	Post	22.51 ± 7.04	22.71 ± 8.19	0.904
	Post-1M	23.00 ± 7.22	22.84 ± 8.73	0.924
	Within group p-value			
	Pre vs Post	0.478	1	/
	Post vs post-1M	0.116	0.776	/
	Overall	0.075	0.947	/
SF-12 PCS	Pre	45.83 ± 7.39	48.20 ± 7.39	0.13
	Post	48.67 ± 0.764	49.59 ± 0.633	0.074
	Post-1M	49.11 ± 0.841	49.82 ± 0.697	0.124
	Within group p-value			
	Pre vs Post	0.13	0.077	/
	Post vs post-1M	0.289	0.477	/
	Overall	0.086	0.074	/
SF-12 MCS	Pre	50.64 ± 9.74	51.76 ± 8.05	0.547
	Post	52.27 ± 8.12	53.40 ± 6.69	0.463
	Post-1M	52.91 ± 7.99	52.98 ± 7.31	0.963
	Within group p-value			
	Pre vs Post	0.126	0.055	/
	Post vs post-1M	0.295	0.412	/
	Overall	0.102	0.127	/
Note: The values are presented as adjusted mean ± standard deviation.				

Table 2: Mean Values of Outcome Measures.

Discussion

This study evaluated the training effects between Tai Chi Robotic and Tai Chi Master on improving balance and muscle strength in Hong Kong Chinese older adults. Both intervention groups demonstrated significant improvements in the Aspire FRS, BBS and self-perceived balance. These findings correspond with previous studies and systematic reviews, supporting the efficacy of Tai Chi in enhancing neuromuscular function and reducing fall risk, especially among the elderly population [13-15]. The observed improvements can be attributed to the biomechanical demands of Tai Chi practice. Through repeated lower limb weight-bearing and sustained postural control like half-squats, controlled transitions between eccentric, concentric and isometric contractions can be achieved. According to Tsang & Hui-Chan (2006), these activities engaged the hip, knee and ankle joints, fostering neuromuscular control and joint stability [16]. Additionally, Tai Chi practice involves three-dimensional centre-of-gravity displacements and weight-shifting movements. As stated by Fong & Ng (2006), these further contributed to the refinement of postural balance and functional mobility [17]. These results proved the benefits of Tai Chi training, highlighting comparable effectiveness of the Tai Chi Robotic Machine and Tai Chi Master training which can both improve balance and reduce fall risk among older adults.

Both intervention groups showed improvements in SLS, but only the TM group demonstrated a statistically significant improvement during post-assessment. This discrepancy may be attributed to

the additional variations on stepping and turning motions in the TM group, which inherently required more single-leg postural components [18]. In contrast, such motions were absent in the Tai Chi Robotic training as the machine only delivered unidirectional training, in which subjects remained in a double-stance position with both feet on the ground. This may account for the lack of significant improvements in SLS performance observed in the TR group despite overall gains in balance, thereby underscoring the task-specific limitations of robotic-assisted training.

The handgrip strength and SF-12 scores showed upward trends in both groups, though not reaching statistical significance. Given that Tai Chi primarily emphasizes lower limb engagement and does not impose substantial mechanical loads on the upper extremities, immediate gains in handgrip strength may be limited. However, handgrip strength is recognized as an indicator for overall muscular strength and endurance, with the process of muscle development generally requiring a longer duration in older adults. Therefore, the non-significant yet positive trends observed in this study may reflect early-stage adaptations, which could evolve into measurable improvements with continued Tai Chi practice [19]. Similarly, while the SF-12 did not show significant changes within the study period, previous research suggests that the psychological and quality-of-life benefits of Tai Chi typically emerge over longer durations of consistent practice [20]. Therefore, it is possible that extended participation in Tai Chi, whether via robotic or traditional means, may lead to more pronounced improvements in both physical health and mental well-being.

Implications

Results of this study showed that the Tai Chi Robotic Machine is a viable alternative or complement to traditional Tai Chi training delivered by a Tai Chi Master, offering comparable improvements in balance and muscle strength among older adults. The integration of such Geron-technology into community-based rehabilitation reflects a meaningful shift toward modernized, technology-assisted interventions, particularly in primary healthcare settings. Given the growing demand for scalable and accessible fall prevention strategies within aging populations, the Tai Chi Robotic Machine stands as a promising innovation capable of addressing these needs.

Traditional Tai Chi training typically requires the presence of a qualified Tai Chi Master, dedicated class space and ongoing scheduling. All of which may constrain participation due to logistical, financial or geographic barriers, potentially increasing long-term costs for both healthcare providers and participants. In contrast, the Tai Chi Robotic Machine offers a more sustainable and cost-effective solution. Once implemented, it can deliver standardized, instructor-free training programs, optimize resource allocation and reduce the burden on healthcare personnel and physical infrastructure in the long run. This supports broader public health goals by enabling early intervention for fall prevention [21].

The Tai Chi Robotic Machine can also improve Tai Chi's accessibility and generalizability, enhancing its potential for widespread adoption beyond clinical or institutional environments. Its application can be extended to residential care homes, community centres, and even individual households. This adaptability makes the device particularly suitable for older adults who may face mobility limitations or prefer to exercise in the comfort and safety of their own homes. By facilitating home-based rehabilitation, the Tai Chi Robotic Machine empowers users to maintain consistent training routines, thereby promoting long-term adherence and functional independence. The generalizability of the Tai Chi Robotic Machine also supports its potential integration into public health initiatives aimed at proactive aging and fall prevention, ensuring the quality and consistency of Tai Chi practices for users to achieve desired training effects.

Limitations

This study is subjected to a relatively high baseline physical function of the subjects. All subjects recruited were community-dwelling older adults, potentially resulting in less pronounced training effects and improvements in the outcome measures. If the same Tai Chi interventions were carried out in settings such as nursing homes and other residential care facilities, targeting elderly that are frailer with lower physical capabilities, the Tai Chi training may yield even more pronounced improvements in balance and muscle strength.

Conclusion

This study provides robust evidence that both the Tai Chi Robotic Machine and the Tai Chi Master training are effective in improving balance and reducing fall risk in older adults. From a practical standpoint, the findings support the integration of the Tai Chi Robotic Machine, a technology-based intervention into community and primary healthcare settings. It can offer a more accessible and cost-effective solution to the challenges of aging populations and limited healthcare resources, allowing improved feasibility and utilization of Tai Chi based balance training programs. The traditional method of Tai Chi practice with a Tai Chi Master also has its merits over the Tai Chi Robotic Machine. Tai Chi Master training proved to benefit SLS more due to its multi-directional training nature and the ability to be more flexible in training variations. These showed that despite both Tai Chi practice methods having similar training effects, both have their own advantages.

The comparable effectiveness of the Tai Chi Robotic Machine to the traditional Tai Chi training method proved that it is an accessible and innovative tool for balance training and fall prevention. Its ability to deliver cost-effective and scalable balance training underscores its relevance in contemporary rehabilitation and public health practice, particularly as societies confront the challenges posed by rapidly aging populations.

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