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ORIGINAL ARTICLE

Effectiveness of a machine-assisted healthy physical fitness promotion program for community elderly

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Abstract

Background: Maintaining physical fitness is important for health of the elderly. How to implement an effective and efficient model is a practical issue. A healthy physical fitness promotion program with machine-assisted exercises was designed for elderly and executed in a community in 2015 and 2016. The program was implemented for 10 to 12 weeks with two (group 1) or three (group 2) sessions per week, and functional fitness tests were conducted before, at the end, and 3 months after the training. This study is to investigate the effectiveness of machine-assisted physical fitness promotion program for the community elderly.

Methods: A retrospective analysis was conducted on the participants' data, including sex, age, height, weight, waist-hip ratio, grip strength, back stretch, chair sit-and-reach, 30-second chair stand, 30-second arm curl, 2-minute step, single-leg standing, 8-ft up-and-go, and body composition. The differences in test results before, at the end, and 3 months after the training and the percentage change at different time intervals between the two groups were compared.

Results: After training, body mass index in group 2 and the test completion time for 8-ft up-and-go in group 1 decline significantly; furthermore, significant increase was noted in the height and number of times of 2-minute step in both groups, and grip strength, number of times of their 30-second arm curl, and 30-second chair stand in group 2. The training effect sustained 3 months after the training in height and number of times of 2-minute step in both groups, and grip strength, number of times of their 30-second arm curl, and 30-second chair stand in group 2.

Conclusion: This study discovered that 10 to 12 weeks of machine-assisted exercise training can improve the elderly community members' body composition, muscle strength, muscle endurance, agility, dynamic balance, and cardiorespiratory endurance. Moreover, with three sessions per week, its effects were even maintained for 3 months after the training.

Keywords: Aged; Exercise; Physical fitness

1. INTRODUCTION

The world population is aging, and Taiwan has one of the world's highest aging rates. It has been an aged society in 2018 and is estimated to become an ultra-aged society by 2026; thus, establishing a localized health promotion system for successful aging has become an urgent matter.[1] The Taiwanese government planned to promote an overall community care model in their 10-year long-term care 2.0 plan, wherein community-based integrated service centers, combined service centers, and long-term care stations in alleys and lanes require practical implementation programs for disability prevention and active health promotion.[2] There are many aspects related to prevent disability and promote health of the elderly in community such as disease prevention, physical fitness, nutrition, oral health, and mental health.[3–6] Maintaining healthy physical fitness is one of the most important strategies. The elderly who has better physical fitness have lower falling risk.[7] Exercise to improve physical fitness can prevent frailty.[8] However, how to carry out the physical fitness promotion program in an effective and efficient way for community elders remains a practical and challenging issue for the government.

Whitehurst et al. (2005) designed 10 functional exercises involving circuit exercise training thrice a week for 12 consecutive weeks for 119 older adults with an average age of 74 years. They discovered that the training enhanced mobility, improved balance, and reduced the incidence of falling, and the respondents were conscious of their physical function improvements.[9] Pin et al.[10] used hydraulic resistance equipment (leg press machines, leg extension machines, and open and close leg machines) with aerobic pedals and subjected older adults in the community to three 50-minute

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sessions of circuit exercise training per week for 12 consecutive weeks. They discovered that after the intervention, the older adults achieved significant improvements in lower-extremity functional fitness, such as in the 30-second chair stand and 8-ft up-and-go tests, as well as in gait stability parameters such as walking speed, walking cadence, and gait cycle duration, which were superior to those of the control group.[10] Ota et al.[11] used six types of low-resistance weight training equipment (training moves included horizontal leg press, leg extension, seated rowing, torso flexion, chest press, and hip abduction) to train older adults aged over 65 years who had long-term care needs. After training twice a week for 12 consecutive weeks, they discovered significant improvements in the participants' timed up-and-go and 10-m walk tests.[11]

Maintaining the financial resource to achieve community health promotion is always a challenge. A company in Su'ao Township, Yilan County, has been invited to participate and fund the health promotion program by the local community. Taiwan resolved to repay the local community through employing the medical expertise of hospital to provide older adults in the community with physical health promotion activities; thus, a physical fitness promotion program has been implemented since August 2015 for older adults aged 65 years and above in the Su'ao community. This provided the study with an opportunity to analyze the physical fitness test data of older community members who had participated in the business feedback—healthy physical fitness promotion program retrospectively.

The aim of the study is to explore the effectiveness of private fund machine-assisted healthy physical fitness promotion program for the community elderly.

2. METHODS

2.1. Study design

A retrospective study was designed and approved by the Human Subject Research Ethics Committee of National Yang-Ming University Hospital (IRB No. 2017A006) to investigate the effectiveness of machine-assisted healthy physical fitness promotion program for community elderly via analysis of the handbook data of all participants.

2.2. Participants

Older adults aged 65 years and above in the Su'ao community, who could walk independently and were screened by a physiatrist to exclude contraindications such as recent fracture, unstable cardiovascular disease, and cognitive impairment, could enter the program. During August 2015 to February 2016, there were totally 48 community elderly participated in the physical fitness promotion program in two courses. They received machine-assisted trainings two sessions per week (total 21 training sessions) and health-education talks in 3 months in each course. From September 2016 and November 2016, 29 community elderly participated in the program and received machine-assisted trainings three sessions per week (total 24 training sessions) and health-education talks in 3 months. In our study, senior citizens who completed at least 10 trainings were recruited. Finally, 36 elderlies who received training twice a week and 23 elderlies who received trainings three times a week were recruited in groups 1 and 2, respectively, for further analyses.

2.3. Intervention

Participants' blood pressure was checked by a nurse before each training session. Under the physical therapist instruction, they took 10 to 15 minutes to warm-up before exercise and cool-down after exercise in each training session. They received 60-minute physical fitness exercise training with an exercise training system called the synchronized monitoring analysis recording care (SMARC). The SMARC system comprised eight exercise machines that are suitable for older adults: the SMARC Series Core Shoulder for upper-extremity alternating lifting (with custom-made mode preset parameter of load level 6 [7.5 kg] and velocity 45°/s); SMARC Series Core Trunk for the backward stretching of the waist and hips through leg stretching (with custom-made mode preset parameter of load level 14 [10.0 kg] and velocity 10°/s); SMARC Series Core Lower Back for alternating trunk flexion while maintaining upper-extremity extension (with custom-made mode preset parameter of load level 7 [8.3 kg] and velocity 20°/s); SMARC Series Core Pelvic for controlling pelvic tilt and rotation while in a sitting position (with custom-made mode preset parameter of load level 8 [7.0 kg] and velocity 25°/s); SMARC Series Core Gait for alternating hip flexion and extension (with custom-made mode preset parameter of load level 10 [10.5 kg] and velocity 40°/s); SMARC Series Core Hip for alternating hip abduction and adduction (with custom-made mode preset parameter of load level 13 [9.5 kg] and velocity 10°/s); SMARC Series Core Knee for knee flexion and extension (with custom-made mode preset parameter of load level 14 [13.5 kg] and velocity 40°/s); and SMARC Series Core Total Body for alternating flexion and stretching of upper and lower extremities together with body rotation (with custom-made mode preset parameter of load level 14 [13.5 kg] and velocity 15°/s). The load level would be adjusted up or down according to participants' ability to achieve Borg Rate of Perceived Exertion (RPE) Scale 12 to 13.[12] In addition to the training at the eight machine stations, four simple activities were interspersed between each station, such as heel raise, semi-squat, lunge, standing hamstring curl, standing hip extensions, seated back and piriformis stretch, and standing weight shift. A group training approach was adopted with a maximum of 12 people within the same period, during which 5 minutes were spent at each station before switching to the next in order, thereby training the older adults' flexibility, muscle strength, muscle endurance, cardiorespiratory endurance, balance, and coordination through machine assistance.

2.4. Measurements

Each training course was implemented for a period of 3 months with two or three training sessions per week, and the functional physical fitness tests were conducted before, at the end, and 3 months after the training course by the same physical therapists and trained assistants. The tests included body composition using body weight, height, body mass index (BMI), waist-hip ratio, 30-second arm curl, grip strength, 30-second chair stand, 8-ft up-and-go, back scratch, chair sit-and-reach, single-leg standing, and 2-minute step to monitor the older adults' physical fitness changes.[13–16]

2.5. Statistical analyses

Data from participants with >10 attendances could be recruited for analysis. For examining changes of physical fitness, test results among before, at the end, and 3 months after the training course were analyzed by repeated measure method in groups 1 and 2. The independent t test was also used to compare the change percentage at different time intervals between two groups. It means significant difference at $p < 0.05$.

3. RESULTS

There were 36 and 23 community elders with average age of 73.8 and 68.0 years, respectively, in groups 1 and 2 recruited in our study. In total, 40 (68%) of the older community members were females. Most educational levels of the participants were below college (**Table 1**).

Comparison of the first (before training) and second (after training) test results indicated a significant decline in BMI in group 2, and the test completion time for 8-ft up-and-go in group 1; furthermore, significant increases were indicated in height and number of times of 2-minute step in both groups, and grip strength,

Table 1

Characteristics of the recruited elderly in two groups 1 and 2

Variables	Group 1	Group 2
Number of recruited elderly	36	23
Gender (male:female)	11:25	8:15
Age, y, mean ± SD	73.8 ± 5.4	68.0 ± 9.4
Education level		
Bachelor	0	2
Senior high school	5	8
Junior high school	10	5
Elementary school	17	6
Nonavailable background	4	2

number of times of their 30-second arm curl, and 30-second chair stand in group 2. Comparison of the second and third (3 months after the training) test results revealed significant increases in body weight, BMI, number of times of 30-second arm curl and decrease in completion time for 8-ft up-and-go in group 2 elders. When comparing the first and third test results, we could find significant increases in body weight, height, and number of times of 2-minute step in both groups, and grip strength, number of times of their 30-second arm curl, and 30-second chair stand in group 2. Although the number of times of 30-second arm curl declined, the completion time for 8-ft up-and-go decreased continuously 3 months after the training in group 1 (**Fig. 1**).

In **Table 2**, percentage change of physical fitness parameters among three timepoints of tests between group 1 and 2 was

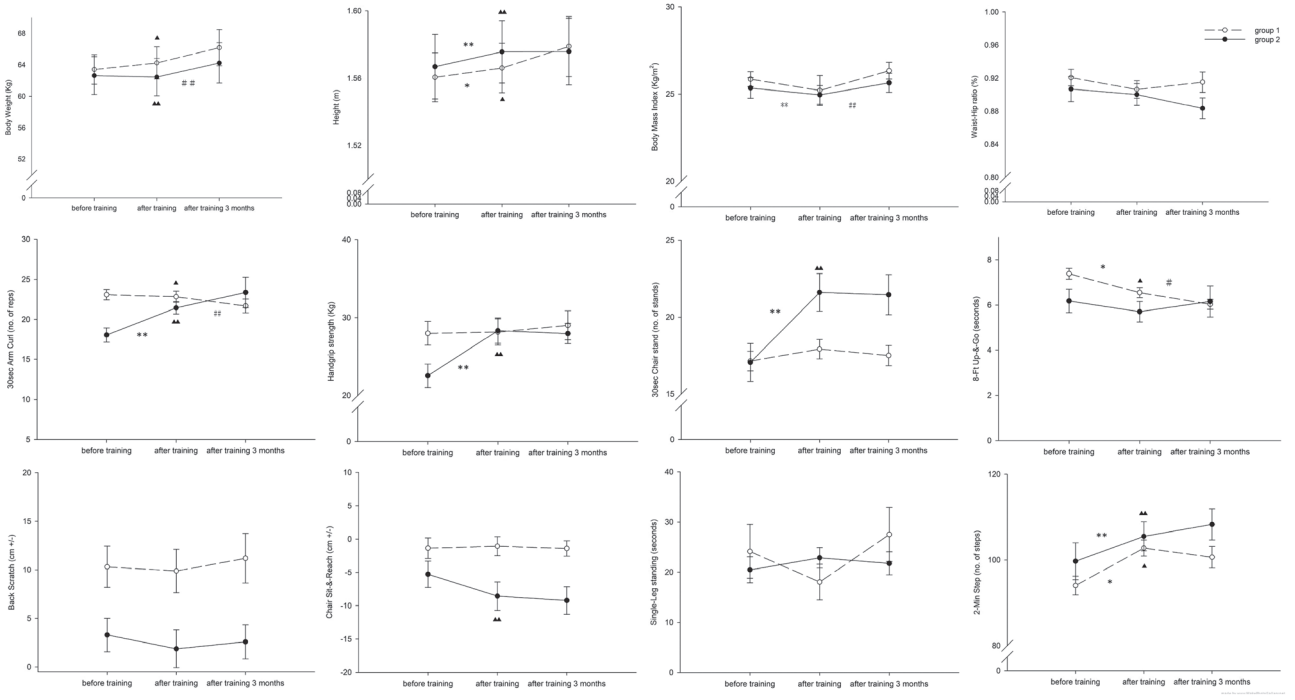

Fig. 1 Results of functional physical fitness tests conducted before, at the end, and 3 months after the training. Repeated measure method. Significant difference when $p < 0.05$, *, ** between before and after training in groups 1 and 2, respectively; #, ## between after and 3 months after the training in groups 1 and 2, respectively; ▲, ▲▲ between before and 3 months after the training in groups 1 and 2, respectively. Group 1: n = 34 to 35, group 2: n = 19 to 20. When the middle fingertip overlaps the other side middle fingertip during back stretch test or the toes during chair sit-and-reach test the distance marked –.

Table 2

Comparison of change percentage of physical fitness parameters between group 1 and 2

	After training vs before training			3 months after training vs after training			3 months after training vs before training		
	Group 1 (n)	Group 2 (n)	*p*	Group 1 (n)	Group 2 (n)	*p*	Group 1 (n)	Group 2 (n)	*p*
Height, m	0.43 ± 0.09 (35)	0.39 ± 0.17 (21)	0.79	–0.05 ± 0.08 (27)	0.004 ± 0.10 (22)	0.67	0.46 ± 0.11 (28)	0.44 ± 0.17 (20)	0.91
Body weight, kg	0.73 ± 0.35 (34)	–0.65 ± 0.38 (21)	0.01*	0.52 ± 0.30 (27)	2.26 ± 0.36 (22)	0.00*	1.11 ± 0.35 (28)	1.66 ± 0.51 (20)	0.36
Handgrip strength, kg	–0.18 ± 1.85 (35)	26.53 ± 4.38 (21)	0.00*	–2.11 ± 1.74 (27)	2.26 ± 3.12 (22)	0.23	–1.66 ± 1.96 (28)	30.73 ± 5.15 (20)	0.00*
30-s arm curl (no of reps.)	0.12 ± 2.47 (35)	21.68 ± 5.58 (21)	0.00*	–7.98 ± 1.88 (27)	6.97 ± 5.30 (22)	0.01*	–7.25 ± 2.76 (28)	23.41 ± 4.27 (20)	0.00*
30-s chair stand (no. of stands)	6.88 ± 3.44 (35)	36.40 ± 6.97 (21)	0.00*	–4.06 ± 2.55 (27)	1.28 ± 2.50 (22)	0.15	1.58 ± 3.22 (28)	34.95 ± 6.71 (20)	0.00*
8-ft up-and-go, s	–11.05 ± 1.55 (35)	–5.71 ± 2.92 (21)	0.08	–6.06 ± 2.54 (27)	5.70 ± 3.13 (22)	0.01*	–16.56 ± 2.46 (28)	–1.34 ± 3.16 (20)	0.00*
Back scratch (cm ±)#	–6.73 ± 10.30 (32)	16.74 ± 23.31 (21)	0.31	19.78 ± 30.14 (27)	–23.64 ± 28.15 (21)	0.31	11.42 ± 14.87 (25)	21.41 ± 18.97 (19)	0.68
Chair sit-and-reach (cm ±)#	–32.35 ± 21.42 (25)	78.56 ± 44.08 (20)	0.03*	–4.30 ± 47.05 (19)	14.31 ± 11.16 (20)	0.70	7.56 ± 42.26 (20)	94.10 ± 48.46 (19)	0.19
Single-leg standing, s	67.82 ± 46.98 (35)	64.06 ± 38.83 (20)	0.96	101.24 ± 43.43 (27)	–1.58 ± 10.77 (21)	0.03*	158.27 ± 96.83 (28)	38.00 ± 18.18 (19)	0.32
2-min step (no. of steps)	9.81 ± 1.67 (35)	8.39 ± 3.25 (21)	0.67	–2.31 ± 2.09 (27)	1.19 ± 2.35 (21)	0.67	7.05 ± 2.42 (28)	5.45 ± 2.43 (19)	0.66

Change percentage of value 2 and 1 = (value 2 – value 1)/(value 1) × 100.

*Statistically significant when $p < 0.05$ with *t* test.

#When the middle fingertip overlaps the other side middle fingertip during back stretch test or the toes during chair sit-and-reach test the distance marked –.

compared. Elders in group 2 showed more body weight decline and more improvement in grip strength, number of times of 30-second arm curl, 30-second chair stand, and chair sit-and-reach than those in group 1 after training. When comparing the results of the third and second test, elders in group 2 had more body weight increase; moreover, the tendency of change was opposite between group 1 and 2 in tests of number of times of 30-second arm curl, 8-ft up-and-go, and single-leg standing. Comparison of the first and third test results revealed more continuous increases in grip strength and number of times of 30-second arm curl, 30-second chair stand in group 2, and more continuous decline in 8-ft up-and-go in group 1.

4. DISCUSSION

After 10 to 12 weeks of machine-assisted exercise training programs two or three times per week for community elderly, the participants' measured-heights were discovered to increase significantly, indicating an improvement in their postures; furthermore, an increase in the number of steps in the 2-minute step test demonstrated improved cardiorespiratory endurance. In group 1, the completion time for the 8-ft up-and-go test was significantly reduced, which indicated significant improvements in agility and dynamic balance after training. Those significant increases in maximum grip strength, the number of repeats of 30-second arm curl, and the number of stands in the 30-second chair stand test indicated improvements in upper- and lower-extremity muscle strength and muscle endurance in group 2. The results of this study were consistent with those of Pin et al. and Ota et al.; both studies discovered that machine-assisted circuit exercise trainings enhanced older adults' functional fitness performance related to the movements mainly trained using the machines.[10,11] Pin et al. used hydraulic resistance equipment and chose leg press machines, leg extension machines, and open and close leg machines that mainly trained lower limbs together with aerobic pedals, subjecting the older adults in the community to three 50-minute sessions of circuit exercise training per week for 12 consecutive weeks. They discovered that the older adults showed significant improvements in their lower-extremity physical fitness such as in the 30-second chair stand and 8-ft up-and-go tests after the intervention.[10] Ota et al. used six low-resistance weight training machines (horizontal leg press, leg extension, seated row, trunk flexion, chest press, and hip abduction machines) to train 17 people aged over 65 years with long-term care needs. After two training sessions per week for 12 consecutive weeks, they discovered significant improvements in the participants' timed up-and-go and 10-m walk tests, whereas they displayed no significant differences in grip strength, lower-extremity muscle strength, single-leg standing, and sit-and-reach tests.[11] In our machine-assisted healthy physical fitness promotion program, the major groups of whole body were trained. Therefore, those older adults' upper-extremity strength, posture-related back muscle endurance, agility, coordination, dynamic balance, cardiopulmonary ability, as well as lower-extremity strength were all improved in group 1 or 2 after training.

However, no significant difference was observed for the single-leg standing, back scratch, and sit-and-reach tests. Despite the main action for the SMARC Series Core Lower Back being to maintain upper-extremity extension for alternating trunk flexion, which could be used to improve lower-extremity flexibility, the training process mainly focused on trunk muscle strength without particular emphasis on trunk and lower-extremity stretching. Hence, the upper- and lower-extremity flexibility and static balance did not improve significantly. Although few training activities related to stretching and static balance were designed in four stations between the eight machine stations in this training program, this did not seem adequate. Future training programs with advanced machine-assisted training function such as real-time individualized training data analyses can be designed and applied to reinforce motivation and improve the specific training effect for the elderly.

If we focus on the training frequency, there were training effect differences between two or three training sessions per week (group 1 vs 2). Muscle strength increase both in upper and lower limbs was more prominent in group 2. With three training sessions per week, the training effect was found not only after training but also 3 months after the training. According to the result of 8-ft up-and-go, coordination and agility could improve after two training sessions per week in group 1. So, the machine-assisted training program could improve elder's coordination with even only two sessions per week in 3 months. But if we want to improve their muscle strength significantly, training frequency as many as three sessions per week is required.

Although, with adequate training frequency, the BMI decreased in group 2 after training. It is interesting to find that the elder's body weight increased after training, especially 3 months after the training programs in group 2. Participants might feel better appetite and be elevated metabolic rate during strengthening exercises.[17] But the caloric cost declined without proportion to intake during the 3-month period after training. That reminds us to include diet education and analyze the body compositions such as lean muscle percentage in future community health promotion program for the elderly.[18]

Increased aging and inactivity of muscles can easily lead to motor impairment and decreased physical strength in older adults, which can in turn result in weakness and even disability. The more common inactive muscles among older adults include the scapula adductor, dorsal extensor, pelvic muscle, thigh extensor, and knee extensor as well as the deep core muscle groups that maintain posture.[19,20] Our program was aimed at these commonly inactive muscle groups to help the people perform low-load repeated exercise and reactivate the inactive neuromuscular system, thereby improving their muscle strength and motor control. Low-load exercises that emphasized posture correctness and contained rhythmic back-and-forth movements were adopted for reasons of safety, as well as to improve motor ability coordination. Inactive muscles can only be practically activated by enabling them to exercise in their proper lengths under the correct postures.[21,22] So, machines like SMARC with electromagnetic resistance control system which can prevent free weight training risk and provide smoothly bidirectional resistance were chosen in this program. Onscreen feedback device was also equipped to facilitate motor coordination and agility for the elders.[23] With few assistant help, the elderly even without high education level can also handle that machine-assist training well during the training period. Finally, except few elders felt muscles soreness after training in first few sessions, no one who participated in this program experienced any apparent adverse impacts.

This community health promotion program was carried out by national university hospital and funded from local private enterprise. The elders who take part in this program were free and not mandatory. It is not surprising that the full attendance rate was not high. The budget to maintain the community health promotion is an important issue. Education to raise the self-awareness of physical fitness for health promotion is also an essential point. Budget from conditionally governmental support and self-payment may be a more suitable solution to support the community health promotion program.[24] We hope that the results of this study can serve as a reference for the government in promoting long-term care programs.

This study contained several limitations. First, data collection was somewhat incomplete because this was a retrospective study and especially in community. Second, no control

group was included for comparison. Third, the older community members who participated in the healthy physical fitness promotion program were capable of walking independently; thus, whether older adults with other functional statuses could achieve such effects is unclear. However, this study did provide valuable information of physical fitness promotion for elderly and executive experience in community. Future studies should design randomized and controlled prospective studies to explore the effectiveness of machine-assisted healthy physical fitness promotion programs for people with various functional statuses.

In conclusion, this study presents a healthy physical fitness promotion program in community, wherein machine-assisted exercise training courses effectively improved the height, muscle strength, muscle endurance, agility, and cardiorespiratory endurance of the elderly in 3 months. Moreover, with three sessions per week, its effects were effectively maintained for 3 months after the training.

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