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Effects of concurrent aerobic and resistance exercise in frail and pre-frail older adults

A randomized trial of supervised versus home-based programs

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Abstract

Background: This study aimed to investigate the effects of supervised and home-based exercise programs on older people with frailty or pre-frailty.

Methods: A total of 146 community-dwelling participants aged 65 and older who were prefrail or frail were randomly allocated into supervised exercise (N=74) and home exercise (N=72) groups. The 3-month supervised exercise training consisted of 3 exercise sessions per week, was performed at a hospital and supervised by a physical therapist. Home exercise participants took instructions on exercise and illustrated exercise handouts. The baseline and 3-month follow-up measurements included body composition, strength of selected upper and lower limb muscle groups, grip and leg press strengths, and five physical performance tests. Mixed-model repeated-measures analysis was applied to determine whether two groups differ in terms of changes before and after the intervention and to compare within-group improvements.

Results: After 3 months of supervised or home-based exercise, the average number of frailty criteria met and fat percentage decreased significantly. Strength of knee extensors, knee flexors and leg press improved significantly in supervised exercise group. In home-based exercise group, the strength of all muscle groups tested improved significantly, except for leg press strength. Walking speed improved in both groups, and timed-up-and-go and timed chair rise tests improved significantly only in supervised exercise group.

Conclusions: Three-month supervised or home-based exercise improved walking speed and strength of the limb muscles. Supervised group showed more improvements in the physical performance tests compared with home-based exercise group.

Abbreviations: 6MW = 6-minute walk, HEG = home-based exercise group, RM = repetition maximum, SD = standard deviation, SEG = supervised exercise group, TCS = timed chair stands, TUG = timed up-and-go.

Keywords: aerobic exercise, exercise training, frailty, resistance training

1. Introduction

The frailty syndrome consists of aging-related symptoms which are associated with a decline in strength, endurance, and physical functions.[1] It is closely associated with increased risk of adverse health events including disability, institutionalization, and death.[1–3] Given that the older population is expected to grow rapidly in the coming decades in Taiwan, strategies to prevent or reverse frailty symptoms should be implemented.[4] One of the major characteristics of frailty syndrome is the loss of muscle mass which is related to a decrease in muscle strength, walking

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All data generated or analyzed during this study are included in this published article and its supplementary information files.

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speed, physical abilities, and endurance.[1] Exercise is widely considered one of the major strategies to maintain or even regain the age-related decease in muscular function and physical reserve, and the effects of exercise programs on older people with frailty have been extensively studied.[5–9] Endurance training and resistance training (which is also known as strength training) have beneficial effects on frail older people as shown in previous studies,[5,10–13] and there are also studies reporting the effectiveness of concurrent resistance and endurance training among this population.[5,14–17] The compliance of an institution-based, supervised exercise program tends to be influenced by various reasons including time and money needed for transportation to and from an institution. Compared with institution-based programs, a home-based exercise program is less costly and does not require transportation, thereby providing convenience for older people with impaired mobility. However, the exercise adherence of the participants would be difficult to be monitored, and progression of exercise intensity is hard to be implemented properly. Previous studies have presented preliminary evidence to support the beneficial effects of home-based exercise programs on disabilities in frail older people,[18] but there is a lack of studies comparing the effects of supervised and home-based exercise programs on muscle strength and endurance of this population.

The aims of the present study were to investigate and compare the effects of supervised and home-based exercise programs on older people with frailty or pre-frailty. We hypothesized that muscle strength and functional performance would improve after participating 3 months of concurrent endurance and resistance exercise program, with better improvement observed in the supervised exercise group.

2. Material and methods

2.1. Definition of frailty

Frailty was defined applying the 5-component criteria proposed by Fried et al in 2001.[1] Shrinking was referred to as having lost at least 3 kg weight during the previous year. Participants with grip strength in the lowest quintile among subgroups of gender and body mass index were classified as those with weakness. Poor endurance and energy were defined by self-reported exhaustion which was recorded by 2 questions in the Center for Epidemiological Studies-Depression Scale.[19] Participants with walking speed in the slowest quintile among gender and height stratification subgroups were classified as slow walkers. Physical activity level was measured by the weighted score of caloric expenditure per week calculated according to the participant report. Those with physical activities in the lowest quintile were classified as having low physical activities. Frailty was defined as meeting at least 3 out of the 5 criteria, and those who met 1 or 2 items were classified as prefrail.

2.2. Participants

The Taichung Community Health Study for Elders is a population-based project which aims to investigate the prevalence, risk factors and potential therapies of frailty and sarcopenia among metropolitan, community-dwelling older people. We invited 2750 citizens aged 65 or older who were registered as residents of the eight administrative neighborhoods ("Li") of North District, Taichung City, Taiwan in June 2009. A total of 1347 older people agreed to participate in this study, and 146 of them were classified as frail or prefrail (Supplemental Digital Content [Figure S1, http://links.lww.com/MD/E547]). The eligible 146 participants were randomized into the supervised exercise group (SEG) or the home-based exercise group (HEG) by a data manager. The allocation sequence was concealed until the moment of assignment. All eligible participants were randomly assigned, using the blocked randomization method with randomly selected block size (2, 4, or 6) to the respective groups. This study was approved and monitored by the Research Ethics Committee of our hospital (DMR 97-IRB-055). Written informed consent was obtained from every participant.

2.3. Measurements

The baseline and follow-up measurements were done 1 week before and within 1 week after the 3-month training program, respectively. Height and weight were measured, and body mass index calculated. Body fat and lean mass percentages were measured using a bioimpedence method Tanita BC-418 (Tanita Corp., Tokyo, Japan). The circumferences of the waist, hip, upper arms, thighs and legs were measured using a tape ruler.

The strength of hand grip, elbow flexors, knee extensors and flexors were measured using a dynamometer (TTM, Tsutsumi, Japan, for hand grip; MicroFET, Hoggan, for other muscle groups). Submaximal leg press strength, between 10 and 15 repetition maximum (RM), was measured using a leg press machine (AURA G3-S70, Matrix Fitness System, USA), and 1-RM leg press strength was then estimated from the resistance measured and the number of repetitions completed using Brzycki formula.[20]

2.4. Physical performance tests

The participants underwent 5 physical performance tests under the instructions of two physical therapists. Walking speed test[21] required the participants to walk at their fastest gait speed for 5 m, and the time utilized was measured. In the timed up-and-go (TUG) test,[22] a participant stood up from a chair, walked 3 m forward and back to the chair, and sat down as fast as possible. The time elapsed was measured. The 6-minute walk (6MW) test[23] required the participant to walk back and forth along a 30-meter walkway as far as possible within 6 min, and the distance traveled was measured. In the single leg stance test,[24] the participants were asked to stand on one leg and maintain balance with the eyes closed. The duration (in seconds) in which a participant can keep standing on one foot, without opening the eyes or touching the floor or other surfaces by any other limbs was recorded. Three trials for each leg were undertaken, and the best result was used for data analysis. In the timed chair stands (TCS) test,[25] a participant first sat in a chair, and then stood up and sat down for 3 times, and the time elapsed was measured.

2.5. Supervised exercise training

Participants in SEG undertook a 3-month exercise training program in the Department of Rehabilitation at our hospital, under the supervision of a physical therapist. The participants undertook 3 exercise sessions per week, with a duration of 1.5 h per session. The exercise training included 10-min warm-up and stretching activities, as well as aerobic exercise and resistance training. Warm-up and stretching included light calisthenics for 5 min and stretching exercises for the major muscle groups.

Aerobic exercise consisted of a 30-min exercise on a lower limb cycle ergometer, including a 2-min warm up stage with zero resistance, and a 2-min cool down stage. The exercise intensity was set at between 70% and 85% of the predicted maximum heart rate which was estimated by deducting the age of the participant from 220, or at which the participant experienced a rating of 13 on the Borg scale of perceived exertion.

Resistance training consisted of strengthening of the elbow flexors utilizing dumb bells, hand grip muscles against grip strength trainers with different resistances, and lower limb muscles with a leg press machine, respectively. The resistance training sessions used 10 repetitions of 75% of the 1-RM for each task as a set. Each participant sequentially undertook a set of hand grip strengthening, elbow flexor strengthening and leg press training, and then repeated the same sequence twice, with a 30-s rest prior to the initiation of the next set of strengthening task. In sum, each participant completed 3 sets of each strengthening tasks during a resistance training session. Care was taken to remind the participants to stop the exercise if they experienced any joint or muscle pain. Progression of exercise intensity was made according to the capacity of each participant. The details of supervised exercise program are summarized in Supplemental Digital Content (Table S1, http://links.lww.com/MD/E548).

2.6. Home-based exercise program

The participants in HEG attended a 15-min session of home-based exercise instructions. They were asked to exercise at least 3 times per week at home. Ten-page illustrated handouts describing calisthenics (including 12 gentle stretching exercises for all limbs and the trunk) and resistance exercise for the upper and lower limbs (e.g., lifting simple weights such as dumbbells, performing push-ups against a wall, standing up from sitting, repeated knee extension and relaxation in a sitting position, and gentle semi-squatting, etc), were given to all participants in HEG. The participants were also asked to perform the calisthenics and resistance exercises for 10 to 15 min at a time. The handouts also recommended the participants to undertake low-intensity aerobic exercises, such as walking or cycling, for 30 min at a time. Participants were not contacted personally or through the telephone until we invited them to undergo a follow up evaluation 3 months after the initial evaluation and exercise instruction.

2.7. Sample size estimation and statistical analysis

The research question used for sample size calculation was whether the exercise intervention program was effectiveness for improving the muscle strength. We supposed that the effect size was estimated to be 2.1 (kg) ($\mu_1 - \mu_0$) and σ was 3.0 (kg). Each group was estimated to be 45 elders given the power of 90% and α is specified at 0.05 (two-sided). If the attrition rate was 38%, each group needed 73 elders.

The demographic characteristics, muscle strength and results of physical performance tests of both groups were described as mean ± standard deviation (SD), and compared with independent *t* test. We applied intention-to-treat approach for data analysis and the last observation was carried forward to fill in the missing data. Thus, for those participants who dropped out and lacked the 3-month follow up results of muscle strength and physical performance, the values obtained at the baseline were used as the final results for analysis. For each outcome measure, mixed-model repeated-measures analysis was conducted to determine whether these two groups differed in terms of the changes in their status before and after the intervention and to compare within-group improvements in muscle strength and physical performance before and after the intervention. Cohen's d statistics for one sample of n differences between paired observations were used to estimate the effect sizes for continuous variables, such as muscle strength and functional performance. The formula used to calculate Cohen's d was $\left[(m_1 - m_2)/\sqrt{(SD_1^2 + SD_2^2)/2}\right]/\sqrt{1-r}$, where m_1 and m_2 are the pre- and post-test mean values, SD_1 and SD_2 are the pre- and post-test SDs, and r is the correlation between the outcome measures in the pre- and post-tests.[26] The odds ratio for dependent samples was used to estimate the effect sizes for categorical variables such as components of frailty. All statistical analyses were performed using Statistics Analysis System (Version 9.4, The SAS institute, Cary, NC) with the significance level set at 0.05.

3. Results

3.1. Participant characteristics

The CONSORT flow diagram is presented in Supplemental Digital Content (Figure S1, http://links.lww.com/MD/E547). Among the 146 participants, 74 were allocated to SEG and 72 to HEG. Twenty-three percent (17/74) of the participants in SEG did not take the 3-month follow up tests. Five of them dropped out because of various diseases or trauma which were not related to the exercise program, and the rest of them quitted because of motivational or logistic reasons. No adverse event of exercise was reported in SEG. The rate of attendance during the intervention was 74.4% in SEG. A total of 32% (23/72) of the participants in HEG disagreed to undertake the 3-month follow up tests.

The two groups did not differ in terms of age, gender, baseline frail status, the baseline circumferences, as well as the muscle strength and functional performance test results, except for mean thigh circumference which was greater in SEG (Tables 1 and 2). The anthropometric data of the two groups are summarized in Table 2.

3.2. Effects of intervention

Compared with baseline conditions, a significantly decrease in fat percentage was observed in both groups ($P = .001$ in SEG and $P = .030$ in HEG), a reduced mean leg circumference was observed in SEG ($P = .025$), and an increased mean thigh circumference was observed in HEG ($P = .035$) at the 3-month follow-up. For mean upper arm circumference, the SEG participants reported a significant reduction from the baseline to the 3-month follow-up (the interaction effect: $F_{(1,144)} = 6.91$, $P = .010$) (Table 2).

After the 3-month exercise program, the strength of knee extensors, knee flexors, and leg press improved significantly in SEG. The strength of grip and elbow flexors in SEG improved by 4% and 6%, respectively, but did not achieve statistical significance. For the HEG participants, the strength of all muscle groups tested improved significantly, except for leg press strength (Table 3). Among the 5 physical performance tests, the walking speed, TUG and TCS performance improved significantly in SEG. Participants in HEG only improve significantly in walking speed ($P = .007$ within-group difference over time) (Table 4). The participants met an average of 1.6 frailty criteria on the baseline,

Table 1

Characteristics of both groups at baseline.

Variable	Supervised exercise group (n=74)	Home-based exercise group (n=72)	P
Age, years	76.49 ± 6.47	76.67 ± 7.30	.875
Age group			
<75	29 (39.2)	28 (38.9)	1.000
≥75	45 (60.8)	44 (61.1)	
Gender			.723
Male	34 (46.0)	30 (41.7)	
Female	40 (54.0)	42 (58.3)	
Number of frailty index	1.54 ± 1.12	1.65 ± 1.05	.534
Frail status			.628
Pre-frail	59 (79.7)	54 (75.0)	
Frail	15 (20.3)	18 (25.0)	

Data are presented as mean ± standard deviation and number (percentage).

Table 2

The anthropometric data of the participants at baseline and after 3 months of exercise.

	Supervised exercise group (n=74)			Home-based exercise group (n=72)			Significance of group differences
Variable	Mean	SD	P	Mean	SD	P	Group × time effect
Weight (kg)							$F_{(1,144)}=0.48$, $P=.489$
Baseline	59.96	10.58		56.87	11.20		
The 3rd month	59.55	10.46		56.73	11.44		
Change after 3 months	−0.40	2.45	.137	−0.14	2.14	.617	
Cohen's d	0.23			0.09			
BMI (kg/m^2)							$F_{(1,144)}=0.37$, $P=.545$
Baseline	24.47	3.24		23.50	3.99		
The 3rd month	24.32	3.30		23.45	4.04		
Change after 3 months	−0.14	1.02	.187	−0.05	0.83	.648	
Cohen's d	0.20			0.09			
Fat%							$F_{(1,143)}=0.64$, $P=.426$
Baseline	32.69	7.81		31.19	9.06		
The 3rd month	31.05	8.22		30.10	9.39		
Change after 3 months	−1.64	4.29	**.001**	−1.09	4.07	**.030**	
Cohen's d	0.54			0.38			
Mean upper arm circumference (cm)							$F_{(1,144)}=6.91$, $P=$**.010**
Baseline	28.53	3.33		27.18	3.15		
The 3rd month	28.14	3.10		27.52	2.82		
Change after 3 months	−0.39	1.78	**.047**	0.34	1.55	.089	
Cohen's d	0.31			0.31			
Waist circumference (cm)							$F_{(1,143)}<0.01$, $P=.967$
Baseline	85.34	8.61		82.85	10.00		
The 3rd month	84.99	9.51		82.47	10.05		
Change after 3 months	−0.34	4.74	.531	−0.38	4.70	.501	
Cohen's d	0.10			0.11			
Gluteal circumference (cm)							$F_{(1,144)}=1.35$, $P=.247$
Baseline	95.51	7.72		94.35	7.98		
The 3rd month	95.71	7.22		93.66	8.07		
Change after 3 months	0.20	4.88	.711	−0.68	4.23	.208	
Cohen's d	0.06			0.23			
Mean thigh circumference (cm)							$F_{(1,144)}=0.95$, $P=.331$
Baseline	47.71	5.07		45.71	5.98		
The 3rd month	48.03	5.10		46.63	5.06		
Change after 3 months	0.32	3.19	.446	0.91	4.07	**.035**	
Cohen's d	0.14			0.32			
Mean leg circumference (cm)							$F_{(1,144)}=0.26$, $P=.608$
Baseline	34.09	2.88		33.22	3.20		
The 3rd month	33.60	2.70		32.89	3.31		
Change after 3 months	−0.49	1.47	**.025**	−0.33	2.18	.132	
Cohen's d	0.47			0.22			

BMI = body mass index, SD = standard deviation.
Change after 3 months was presented as absolute value of the status at the 3rd month minus the status at baseline.
Bold values denote statistical significance at the $P < 0.05$ level.

Table 3

The muscle strength of the participants at baseline and after 3 months of exercise.

	Supervised exercise group (n=74)			Home-based exercise group (n=72)			Significance of group differences
Variable	**Mean**	**SD**	**P^***	**Mean**	**SD**	**$P^†$**	**Group × time effect***
Grip strength (kgw)							$F_{(1,144)}=1.02$, $P=.314$
Baseline	24.11	7.35		23.73	7.82		
The 3rd month	25.14	7.15		25.70	9.75		
Change after 3 months	1.02	4.18	.125	1.97	6.93	**.004**	
Cohen's d	0.35			0.41			
Strength of elbow flexors (N)							$F_{(1,143)}=0.35$, $P=.553$
Baseline	180.02	60.79		168.26	69.35		
The 3rd month	190.90	63.58		184.27	69.65		
Change after 3 months	11.11	52.49	.063	16.02	48.08	**.008**	
Cohen's d	0.29			0.47			
Strength of knee extensors (N)							$F_{(1,144)}=0.42$, $P=.516$
Baseline	217.21	75.02		201.46	75.37		
The 3rd month	237.83	78.10		228.37	79.11		
Change after 3 months	20.62	59.11	**.003**	26.91	57.48	<**.001**	
Cohen's d	0.49			0.66			
Strength of knee flexors (N)							$F_{(1,144)}=0.10$, $P=.752$
Baseline	156.12	55.34		145.40	56.97		
The 3rd month	170.51	56.32		157.67	54.95		
Change after 3 months	14.39	41.49	**.003**	12.27	39.17	**.011**	
Cohen's d	0.49			0.44			
Maximum strength of leg press (kg)							$F_{(1,137)}=7.53$, $P=$**.007**
Baseline	49.66	21.23		42.00	19.23		
The 3rd month	57.42	26.66		42.13	22.74		
Change after 3 months†	9.22	17.32	<**.001**	2.11	12.90	.378	
Cohen's d	0.66			0.01			

SD=standard deviation.
* Within-group differences and group differences were analyzed by using mixed-model repeated-measures analysis.
† Change after 3 months was presented as absolute value of the status at the 3rd month minus the status at baseline.
Bold values denote statistical significance at the $P < 0.05$ level.

Table 4

The results of physical performance tests of the participants at baseline and after 3 months of exercise.

	Supervised exercise group (n=74)			Home-based exercise group (n=72)			Significance of group differences
Variable	**Mean**	**SD**	**P**	**Mean**	**SD**	**P**	**Group × time effect**
Walking speed (m/s)							$F_{(1,142)}=0.01$, $P=.922$
Baseline	0.73	0.23		0.71	0.24		
The 3rd month	0.79	0.23		0.78	0.33		
Change after 3 months	0.07	0.19	**.009**	0.07	0.25	**.007**	
Cohen's d	0.51			0.43			
Timed up and go test (s)							$F_{(1,142)}=4.91$, $P=$**.028**
Baseline	9.65	5.28		10.22	7.20		
The 3rd month	8.69	4.26		10.60	8.03		
Change after 3 months	−0.96	2.86	**.008**	0.05	2.79	.994	
Cohen's d	0.47			0.19			
Six-minute walking test (m)							$F_{(1,137)}=0.71$, $P=.401$
Baseline	398.51	116.17		392.90	116.81		
The 3rd month	405.59	116.87		389.41	129.31		
Change after 3 months	11.29	71.30	.210	1.09	72.71	.975	
Cohen's d	0.09			0.07			
Single leg stance (s)							$F_{(1,138)}=0.25$, $P=.619$
Baseline	3.89	3.47		4.02	3.19		
The 3rd month	3.86	4.68		4.35	3.67		
Change after 3 months	−0.03	5.45	.949	0.34	2.77	.529	
Cohen's d	0.01			0.17			
Timed chair stand (s)							$F_{(1,140)}=3.43$, $P=.066$
Baseline	6.38	3.01		6.19	4.05		
The 3rd month	5.86	2.71		6.20	4.00		
Change after 3 months	−0.53	1.88	**.008**	0.01	1.47	.994	
Cohen's d	0.39			0.01			

SD=standard deviation.
Change after 3 months was presented as absolute value of the status at the 3rd month minus the status at baseline.
Bold values denote statistical significance at the $P < 0.05$ level.

Table 5

Frailty criteria met among participants in both groups.

Variable	Supervised exercise group (n=74) n	%	*P*	Home-based exercise group (n=72) n	%	*P*	Significance of group differences Group × time effect
Weight loss							$F_{(1,144)}=0.07$, $P=.796$
Met at baseline	11	14.9		18	25.0		
Met after 3 months	8	10.8		12	16.7		
Change after 3 months			.454			.204	
Worse	5	6.8		3	4.2		
Better	8	10.8		9	12.5		
Unchanged	61	82.4		60	83.3		
Odds ratio	1.60			3.00			
Exhaustion							$F_{(1,144)}=0.55$, $P=.459$
Met at baseline	8	10.8		11	15.3		
Met after 3 months	6	8.1		13	18.1		
Change after 3 months			.567			.639	
Worse	4	5.4		5	6.9		
Better	6	8.1		3	4.2		
Unchanged	64	86.5		64	88.9		
Odds ratio	1.50			0.60			
Low physical activity							$F_{(1,144)}=0.75$, $P=.388$
Met at baseline	11	14.9		11	15.3		
Met after 3 months	10	13.5		6	8.3		
Change after 3 months			.799			.17	
Worse	3	4.1		0	0.0		
Better	4	5.4		5	6.9		
Unchanged	67	90.5		67	93.1		
Odds ratio	1.33			11.00			
Slow walker							$F_{(1,144)}=0.01$, $P=.935$
Met at baseline	38	51.4		36	50.0		
Met after 3 months	28	37.8		27	37.5		
Change after 3 months			.075			.102	
Worse	4	5.4		3	4.2		
Better	14	18.9		12	16.7		
Unchanged	56	75.7		57	79.1		
Odds ratio	3.50			4.00			
Weakness (poor grip strength)							$F_{(1,144)}=0.40$, $P=.528$
Met at baseline	46	62.2		43	59.7		
Met after 3 months	36	48.7		38	52.8		
Change after 3 months			.070			.356	
Worse	2	2.7		5	6.9		
Better	12	16.2		10	13.9		
Unchanged	60	81.1		57	79.2		
Odds ratio	6.00			2.00			

	Mean	SD		Mean	SD		
Average number of criteria met							$F_{(1,144)}=0.04$, $P=.852$
Baseline	1.54	1.12		1.65	1.05		
The 3rd month	1.19	1.11		1.33	1.07		
Change after 3 months	−0.35	1.15	**.004**	−0.32	0.88	**.009**	
Cohen's d	0.43			0.51			

SD=standard deviation.

Change after 3 months was presented as absolute value of the status at the 3rd month minus the status at baseline.

Bold values denote statistical significance at the $P < 0.05$ level.

and there was no difference between SEG and HEG. After the 3-month exercise program, the average number of met frailty criteria significantly decreased in both groups ($P=.004$ in SEG and $P=.009$ in HEG within-group difference, Table 5).

4. Discussion

Our results showed that, a 3-month home-based exercise program improved walking speed and strength of the limb muscles as did a supervised program, though SEG showed more improvements in the physical performance tests compared with HEG. The participants in both SEG and HEG showed improvements in their walking speed as well as knee extensor and flexor strengths. However, only those in HEG showed significant improvements in hand grip and elbow flexor strengths, while only those in SEG showed improvements in leg press strength and performances in the TUG and TCS tests. The present study applied a concurrent training program which included both resistance and endurance training. Several guidelines or recommendations[27–29] support combining resistance and endurance training to promote health and physical functions of older people. While strength training enhances neuromuscular activities and increases muscle mass, strength as well as power output, endurance training improves the cardiopulmonary capacity. Moreover, it has been reported that strength training may improve aerobic endurance measured by time to exhaustion while performing a task, without increasing the maximum oxygen uptake.[30] Endurance training also positively affects muscle strength if performed using cycle ergometers.[16,17]

4.1. Muscle strength, physical performance and others

The participants in HEG showed improvement in the strength of all muscle groups tested, with the exception for the leg press strength. Given the specificity of physiological adaptation to training, the leg press performance improved more significantly in SEG which incorporated leg press training to strengthen the lower limbs. However, leg press training requires a relatively bulky instrument that is not available in most households. The simple home-based exercises for lower limb strengthening performed in this study helped strengthen the lower limb muscles of the participants without using bulky and expensive instruments. The hand grip and elbow flexor strength increased in SEG (with effect sizes of 0.35 and 0.29, respectively), but such improvement did not reach statistical significance. This result may be attributed to the fact that, we advised our participants to stop the exercise whenever they experienced any musculoskeletal discomfort to avoid injury. Therefore, these participants might be trained below their optimal level of effort.

Walking speed is associated with survival and considered an important indicator of health and functional status.[31] In the present study, the walking speed improved in both groups. To prevent the gait speed of the frail older people from decreasing further, proactive measures for preserving their walking speed and cardiopulmonary endurance (e.g., walking or cycling) should be implemented. The results of the present study suggest that, a home-based exercise program with minimal supervision can effectively increase walking speed. Implementing an effective home-based exercise program among community-dwelling older population is potentially a widely applicable way to attenuate their functional decline.[18]

The supervised exercise program used cycle ergometer exercise for endurance training, and the improvement of the 6MW performance after the 3-month exercise program was insignificant. In the present study, the 6MW test was used to measure cardiopulmonary capacity. Given that cycling exercise differs biomechanically from walking, the 6MW test may underestimate the gain in cardiopulmonary capacity obtained by participating in cycle ergometer exercise. A graded exercise test using cycle ergometer may be more sensitive to detect the cardiopulmonary improvement among the participants in SEG because of specificity of training effect.

In the present study, fat percentage significantly decreased in both groups. Although a significant decrease in fat percentage was not reported in previous studies focusing on exercise intervention for frail older adults,[12,32] muscle fat infiltration had been shown to decrease after 12 weeks of multiple-component exercise which incorporated muscle power training among nonagenarians.[13] This result may be the mechanism underlying the decrease in fat percentage in the present study. The average number of frailty criteria met by participants decreased significantly in both exercise groups in present study. The tendency of reversing of frailty status was also reported by Kim et al,[32] thereby indicating that a 3-month exercise program is effective to decrease the number of frailty criteria met by the participants.

4.2. Study limitation

The present study possessed several limitations. First, the drop-out rates were high in both groups. Thus, the effects of training based on the intention-to-treat analysis may be underestimated. Second, we did not arrange follow-up tests in longer terms to evaluate the retention of training effect. Third, for evaluation of cardiopulmonary capacity, we utilized 6MW test instead of graded exercise testing with gas analysis; 6MW test may underestimate the improvement of the cardiopulmonary endurance obtained via cycle ergometer training. Finally, the present study did not include a control group in which no exercise intervention was given.

5. Conclusion

In the present study, the 3-month supervised concurrent resistance and endurance exercise program improved the strength of the knee extensors, knee flexors, and leg press strength of the participants in addition to their walking speed and performances in the TUG and TCS tests. Meanwhile, the 3-month home-based exercise program improved walking speed and strengths for all tested muscle groups of the participants, except for leg press strength. Our results suggest that, even with a high drop-out rate, an unsupervised home-based exercise program provided for community-dwelling frail and prefrail older people is still effect to improve their muscle performance and walking speed, which are important indicators of health and physical function among this population. Further studies are needed to elucidate the most suitable protocols of home-based exercise programs in order to facilitate better program adherence and outcomes of physical performance performances tests in addition to muscle strength and walking speed.

Author contributions

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