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Effects of Exercise on the Improvement of the Physical Functions of the Elderly

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Abstract. The purpose of this study is to clarify the effects of exercise on the improvement of the physical functions of the elderly. Ten males and thirty-four females, 44 in total, living in or visiting health care facilities and special nursing homes for the elderly who were able to either walk independently or with walking aids were randomly divided into a treatment intervention group (TIG) and a control group (CG). The average age of the TIG was 84.4 ± 5.6 years old, and that of the CG was 85.6 ± 4.8 years old respectively. The training exercises of the TIG were standing up from a chair grasping parallel bars and raising arms with pet bottles 2 or 3 times a week for 6 months. In the TIG, increased mean values of each estimation parameter were recognized: muscle strength of upper and lower limbs, grip strength, thigh circumference, standing up, the movement of raising arms, walking time and number of steps for 10 m, Functional Reach Test and Timed up & Go Test. Moreover, significant differences between the TIG and the CG were found in each evaluation item ($p<0.05$). This study suggests that the continuation of light-load exercise is effective and imperative for the elderly to keep and improve their physical functions.
Key words: Elderly, Exercise, Muscle strengthening

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INTRODUCTION

Japan is rapidly entering an era of an aged society due to medical developments, improved life styles, falling birthrate, and other factors. According to the Statistics Bureau, Ministry of Internal Affairs and Communications, the number of the elderly the age of 65 or older reached 26.06 million in April 2006, comprising 20.4% of the total population of Japan[1)]. Among them, the number of those aged 75 or older is increasing yearly. Their number has reached 11.89 million (9.3%), and is expected to increase significantly in future. It is predicted that the number of the over 75s will exceed that of the 65–75s by the year 2020, and reach 20 million by the year 2035 due to the aging of the first baby boomer population.

In response to this rapid aging of the population, it is indispensable to implement exercise programs for not only disabled elderly but also healthy elderly in order to minimize lowering of body function, maintain mind and body functions, and promote a healthy and comfortable daily life.

Before the implementation of exercise programs, we should understand that body functions of the elderly decline with age[2)], and that further loss of body function is brought about by lack of exercise due to lifestyle[3)], and physical inactivity due to higher morbidity. Based on these, it is important to consider elderly people's physical capabilities and motor functions and the factors contributing to these, including muscle strength, muscle endurance, alertness, balance, flexibility, physical endurance and power, in order to develop quality exercise programs for intervention use for the elderly.

In past studies on resistance training in the elderly, increased muscle strength without morphological changes such as muscular hypertrophy was reported, which supported the then dominant view that neural factors are expected to be improved by trainings. However, recent studies on exercise programs and resistance training in the elderly have shown muscle hypertrophy as seen in adolescents[4, 5] and changes in the composition of fast and slow twitch fibers[6]. Thus, it is considered that various effects, including alteration of the muscle itself, are expected from resistance training in the elderly as well.

Takeuchi et al.[7, 8] reported that lowering of standing-up and walking abilities in the elderly did not contribute to a simple decrease in body function which could be recovered by conventional rehabilitation, but was due to lowering of energy through decreased activity and decline in physical strength, and said that power rehabilitation by weight training was the most effective procedure to recover these abilities.

Hisano et al.[9–12] implemented a three-month exercise program for 10 female subjects with a mean age of 70, employing tubes for muscle training. They observed a remarkable increase in the mass of the greater psoas and other muscles, as well as longer stride and improved walking speed. They concluded that the mass of the greater psoas and femoral extensor muscles are the most influential factors on stride and that focused reinforcement of these muscles would help maintain and improve walking ability which is one of the most important functions required in the life of the elderly.

Fiatarone et al.[13] implemented an eight-week muscle strength exercise for nine elderly persons with a mean age of over 90 by applying a load of 50–80% of their maximum muscle strength to the femoral muscles three times a week. They reported increases in strength and mass of quadriceps by 174% and 9%, respectively, as well as improved walking ability.

Fukunaga et al.[14, 15] implemented a six-month low intensity training including half squats, push-ups, and sit-ups (the action to tilt the trunk backward from perpendicular to 45 degrees to the floor and returning it slowly to the original position while sitting with the arms crossed over the chest and the knees flexed at the angle of 90 degrees) in 70 female subjects aged between 60 and 80 who were regularly attending a sports center. They observed a significant increase in the strength of knee joint extension and flexion muscle groups and the thickness of forearm muscles. Also, they described some prerequisites for the resistance training for the elderly. Those were that the training should be one i) that could be carried out by those with low muscle strength, ii) that accompanies little risk of injury or accidents, and iii) that requires no special facility or equipment and can be carried out easily at home.

Muscle training tends to be thought of as requiring weight training equipment as seen at community sport facilities or private gyms, unlike walking exercise that can be easily carried out without the use of special equipment. Indeed, when weight training equipment is used, increase in muscle mass and improvement in activities of daily living (ADL) are observed in the elderly, and the effect has been confirmed by many studies. However, it is impractical to recommend only muscle training with the use of equipment in public or community rehabilitation settings as well as in the medical settings since the subjects of the exercise program are mainly elderly people[12].

In order to resolve this issue, it is important to develop muscle training programs that are easily carried out in any setting, including nursing facilities and homes as well as hospitals, and evaluate their benefits. Though there have been some reports on muscle training programs in the 65–75s using subjects' own weight or tubes as loads, there have been few studies that have quantitatively evaluated the effect of exercise programs in the over 75s, leaving many issues to be studied.

Based on the above, this study verified the effect of an exercise program to improve physical function in the over 75s.

SUBJECTS AND METHODS

The subjects of this study were 52 ambulatory people (11 males and 41 females), including those using walking aids (T canes), who resided in or attended geriatric health care facilities or special nursing homes. They were randomly allocated to the intervention group (n=33) and the control group (n=19).

Analysis was performed on results from a total of

44 subjects (10 males and 34 females) including 27 subjects in the intervention group and 17 subjects in the control group, excluding 8 subjects who withdrew during the 6-month study period (5 cases of pneumonitis, 2 cases of hospital change, and 1 case of cerebral infarct).

The mean age, height, and weight of the intervention group was 84.4 ± 5.6 years (ranging between 75 and 96), 145.9 ± 8.7 cm, and 50.8 ± 8.9 kg, respectively, and those of the control group were 85.6 ± 4.8 years (ranging between 76 and 96), 145.9 ± 10.0 cm, and 47.5 ± 8.8 kg, respectively. BMI (body mass index) of the intervention and the control groups were 23.9% and 22.3%, respectively. There was no significant difference between the groups in these parameters. Subjects received an explanation about the purpose and methods of this study and were asked for their cooperation for the study. At the same time, subjects received an explanation that those in the intervention group would participate in the assessment and exercise programs while those in the control group would participate only in the assessment, after which they gave their consent.

Subjects in the intervention group performed a rising-from-chair motion exercise while gripping parallel bars (Fig. 1), and upper limb elevation exercise using PET bottles (Fig. 2). In the latter exercise, subjects held a 500 ml PET bottles filled with water in each hand, and moved both upper limbs up and down and back and forth in the sitting position on the chair. Bending and stretching exercises of the elbow joints were also performed.

Fig.1. Rising-from-chair motion exercise with gripping parallel bars.

Fig.2. Upper limb elevation exercise using PET bottles.

One set of each exercise consisted of 10 repetitions and four to six sets were performed with rests between sets. All the subjects in the intervention group performed each exercise at the same time at each facility.

The load of the exercise, i.e., the amount or repeats of exercise was set using the Borg scale, so that each subject's perception of the exercise was within the range of Borg scale 11 "Fairly Light" to Borg scale 13 "Somewhat Hard".

However, in case patients felt it difficult to continue the exercise in the middle of the session due to fatigue or other reasons, they could immediately discontinue the set and the rest of the exercise was based on self-assessment. The exercise program was performed two to three times a week for 6 months.

Subjects in both groups participated in group exercises and recreation activities in the facility as usual, and only subjects in the intervention group performed the above-mentioned exercise program additionally. Also, subjects in both groups kept up their daily life activities without change from before the study.

For the assessment of the effect of the exercise program, the following items were measured and compared before and at three and six months after the start of the intervention: i) muscle group strength of elbow joint flexor and extensor, hip joint abductor and adductor, knee joint flexor and extensor, ankle joint dorsiflexor and plantar flexor; ii) right and left grip strength; iii) circumference of right and left thighs at 5, 10, and 15 cm above the patella; iv) maximum count of continual repetition, and maximum count in 10 seconds of rising-from-chair motion; v) maximum count of continual repetition, and maximum count in 10 seconds of upper limb elevation with water-filled PET bottles; vi) time and number of steps required for walking 10 m; vii) functional reach tests (hereinafter referred to as FRT) of both sides; and viii) 3 m timed “up and go” test (hereinafter referred to as TUGT) of both sides.

Muscle strength was measured several times as isometric muscle strength of each joint using ISOFORCE GT-310 (OG Giken Co., Ltd.), and the greatest value (kgf) was used as the maximum muscle strength.

For statistical analysis, Friedman’s test was used for the rising-from-chair motion, upper limb elevation, and number of steps during 10 m walking before and after the intervention, and two-way ANOVA without repetition was used for the rest of the evaluation items. Scheffe test was used as a post-hoc test. For the comparison between the intervention and the control groups, the Mann-Whitney test was used. Stat View ver. 5.0 and SPSS 10.0J were used for statistical processing, and p values of less than 5 percent were considered significant.

RESULTS

Averages of measurement values before (I), 3 months after (II) and 6 months after (III) the intervention were compared between the intervention and the control groups (Tables 1 and 2).

Changes in muscle strength

1) Elbow joint flexor and extensor group

Regarding elbow joint flexor group, significant increases were observed in the intervention group for both sides. Right flexor strength changed from 5.4 ± 1.4 kgf to 8.5 ± 2.1 kgf and 9.0 ± 2.4 kgf with rates of change of 61.0% and 69.5%, and left flexor strength changed from 5.5 ± 1.6 kgf to 7.9 ± 1.9 kgf and 8.2 ± 2.0 kgf with rates of change of 51.7% and 58.3%. While, significant decreases were observed in the control group for both sides. Right flexor strength changed from 7.2 ± 2.8 kgf to 6.3 ± 2.5 kgf and 6.1 ± 2.5 kgf with rates of change of –10.8% and –13.7%, and left flexor strength changed from 7.0 ± 2.6 kgf to 6.1 ± 2.4 kgf and 5.8 ± 2.3 kgf with rates of change of –12.2% and –16.9%. There were significant differences between both groups in the rates of change of right and left.

Regarding elbow joint extensor group, significant increases were observed in the intervention group for both sides. Right extensor strength changed from 4.4 ± 1.2 kgf to 5.8 ± 1.3 kgf and 6.3 ± 1.5 kgf with rates of change of 39.3% and 50.2%, and left extensor strength changed from 4.3 ± 1.1 kgf to 5.6 ± 1.4 kgf and 5.7 ± 1.5 kgf with rates of change of 34.4% and 38.1%. While, significant decreases were observed in the control group for both sides. Right extensor strength changed from 5.4 ± 1.6 kgf to 4.6 ± 1.3 kgf and 4.2 ± 1.3 kgf with rates of change of –14.2% and –21.4%, and left extensor strength changed from 5.3 ± 1.4 kgf to 4.4 ± 0.9 kgf and 4.1 ± 0.8 kgf with rates of change of –16.6% and –20.4%. There were significant differences between both groups in the rates of change of right and left.

2) Hip joint abductor and adductor group

Regarding hip joint abductor group, significant increases were observed in the intervention group for both sides. Right abductor strength changed from 6.4 ± 2.0 kgf to 9.2 ± 2.3 kgf and 9.5 ± 2.6 kgf with rates of change of 50.3% and 55.5%, and left abductor strength changed from 6.1 ± 2.0 kgf to 8.7 ± 2.5 kgf and 8.8 ± 2.8 kgf with rates of change of 45.6% and 46.3%. While, significant decreases were observed in the control group for both sides. Right abductor strength changed from 7.9 ± 3.3 kgf to 6.4 ± 3.2 kgf and 5.7 ± 2.7 kgf with rates of change of –18.9% and –27.3%, and left abductor strength changed from7.2 ± 3.5 kgf to 5.9 ± 2.8 kgf and 5.0 ± 2.0 kgf with rates of change of –22.2% and –32.2%. There were significant differences between both groups in the rates of change of right and left.

Regarding hip joint adductor group, significant increases were observed in the intervention group for both sides. Right adductor strength changed from 5.5 ± 1.7 kgf to 8.4 ± 2.3 kgf and 8.6 ± 2.5 kgf with rates of change of 57.6% and 60.8%, and left adductor strength changed from 5.6 ± 1.6 kgf to 7.7 ± 2.6 kgf and 8.1 ± 2.9 kgf with rates of change of 38.0% and 43.7%. While, significant decreases were observed in the control group for both sides. Right adductor strength changed from 7.9 ± 3.1 kgf to 6.6 ± 3.1 kgf and 6.0 ± 2.9 kgf with rates of change of –16.6% and –24.7%, and left adductor strength changed from 7.2 ± 3.2 kgf to 5.9 ± 2.5 kgf and 5.4 ± 2.0 kgf with rates of change of –15.8% and –22.5%. There were significant differences

Table 1. Comparison of averages of each parameters in the intervention group

		I. Before intervention (N=27)	II. After 3 months (N=27)	III. After 6 months (N=27)	p value	Scheffe test
Elbow joint flexor group (kgf)	Right	5.4 ± 1.4	8.5 ± 2.1	9.0 ± 2.4	**	I<II, I<III
	Left	5.5 ± 1.6	7.9 ± 1.9	8.2 ± 2.0	**	I<II, I<III
Elbow joint extensor group (kgf)	Right	4.4 ± 1.2	5.8 ± 1.3	6.3 ± 1.5	**	I<II, I<III, II<III
	Left	4.3 ± 1.1	5.6 ± 1.4	5.7 ± 1.5	**	I<II, I<III
Hip joint abductor group (kgf)	Right	6.4 ± 2.0	9.2 ± 2.3	9.5 ± 2.6	**	I<II, I<III
	Left	6.1 ± 2.0	8.7 ± 2.5	8.8 ± 2.8	**	I<II, I<III
Hip joint adductor group (kgf)	Right	5.5 ± 1.7	8.4 ± 2.3	8.6 ± 2.5	**	I<II, I<III
	Left	5.6 ± 1.6	7.7 ± 2.6	8.1 ± 2.9	**	I<II, I<III
Knee joint flexor group (kgf)	Right	4.7 ± 1.5	6.4 ± 2.1	6.9 ± 2.3	**	I<II, I<III
	Left	4.5 ± 1.5	6.0 ± 1.8	6.4 ± 2.1	**	I<II, I<III
Knee joint extensor group (kgf)	Right	7.0 ± 2.3	11.6 ± 3.0	12.0 ± 3.0	**	I<II, I<III
	Left	6.8 ± 2.3	10.8 ± 2.6	11.5 ± 2.9	**	I<II, I<III
Ankle joint dorsiflexor group (kgf)	Right	4.6 ± 1.6	7.2 ± 1.8	7.4 ± 2.1	**	I<II, I<III
	Left	4.4 ± 1.1	6.8 ± 1.8	6.9 ± 2.1	**	I<II, I<III
Ankle joint plantar flexor group (kgf)	Right	4.9 ± 1.3	11.7 ± 3.9	13.7 ± 5.3	**	I<II, I<III, II<III
	Left	4.6 ± 1.2	12.0 ± 4.0	13.6 ± 5.3	**	I<II, I<III
Grip strength (kg)	Right	16.2 ± 5.9	18.0 ± 5.2	17.8 ± 5.2	**	I<II, I<III
	Left	14.0 ± 4.4	16.1 ± 4.3	15.9 ± 4.4	**	I<II, I<III
Circumference of thigh at 15 cm from	Right	42.7 ± 3.9	43.5 ± 4.4	43.4 ± 4.4	**	I<II, I<III
patella (cm)	Left	42.3 ± 4.1	43.1 ± 4.2	43.0 ± 4.3	**	I<II, I<III
Circumference of thigh at 10 cm from	Right	39.6 ± 3.7	40.1 ± 4.0	40.0 ± 4.1	n.s	
patella (cm)	Left	39.3 ± 3.8	39.9 ± 3.8	39.7 ± 3.9	**	I<II
Circumference of thigh at 5 cm from	Right	36.2 ± 3.7	36.7 ± 3.8	36.7 ± 4.0	n.s	
patella (cm)	Left	36.2 ± 3.7	36.6 ± 3.6	36.5 ± 3.8	**	I<II
Maximum count of rising-from-chair motion		25.6 ± 17.7	44.7 ± 28.7	52.0 ± 29.1	**	I<II, I<III, II<III
Maximum count of rising-from-chair motion in 10 seconds		4.5 ± 1.1	4.9 ± 1.0	5.0 ± 1.3	**	I<II, I<III
Maximum count of upper limb elevation		35.9 ± 20.4	64.3 ± 35.5	71.0 ± 35.1	**	I<II, I<III
Maximum count of upper limb elevation in 10 seconds		6.3 ± 1.7	7.7 ± 1.6	7.6 ± 1.6	**	I<II, I<III
10 m walking time (sec)	Right	12.5 ± 5.3	11.3 ± 4.9	11.8 ± 5.3	*	I>II
Number of steps in 10 m	Left	24.2 ± 8.1	23.1 ± 8.5	23.7 ± 9.3	*	I>II
FRT (cm)	Right	18.6 ± 6.5	22.0 ± 5.9	20.7 ± 5.7	**	I<II, I<III
	Left	18.2 ± 5.1	21.3 ± 4.6	20.5 ± 4.8	**	I<II, I<III
TUGT (sec)	Right	14.3 ± 4.7	13.1 ± 5.2	13.0 ± 5.6	**	I>II, I>III
	Left	14.3 ± 5.2	13.1 ± 5.6	13.1 ± 5.9	**	I>II, I>III

*p<0.05, **p<0.01

between both groups in the rates of change of right and left.

3) Knee joint flexor and extensor group

Regarding knee joint flexor group, significant increases were observed in the intervention group for both sides. Right flexor strength changed from 4.7 ± 1.5 kgf to 6.4 ± 2.1 kgf and 6.9 ± 2.3 kgf with rates of change of 36.5% and 46.3%, and left flexor strength changed from 4.5 ± 1.5 kgf to 6.0 ± 1.8 kgf and 6.4 ± 2.1 kgf with rates of change of 34.4% and 41.5%. While, significant decreases were observed in the control group for both sides. Right flexor strength changed from 6.7 ± 2.7 kgf to 5.4 ± 2.5 kgf and 4.8 ± 2.2 kgf with rates of change of –20.2% and –28.4%, and left flexor strength changed from 6.4 ± 2.6 kgf to 5.0 ± 2.2 kgf and 4.7 ± 1.9 kgf with rates of change of –20.0% and –24.9%. There were significant differences between both groups in the rates of change of right and left.

Table 2. Comparison of averages of each parameters in the control group

		I. Before intervention (N=17)	II. After 3 months (N=17)	III. After 6 months (N=17)	p value	Scheffe test
Elbow joint flexor group (kgf)	Right	7.2 ± 2.8	6.3 ± 2.5	6.1 ± 2.5	**	I>II, I>III
	Left	7.0 ± 2.6	6.1 ± 2.4	5.8 ± 2.3	**	I>II, I>III
Elbow joint extensor group (kgf)	Right	5.4 ± 1.6	4.6 ± 1.3	4.2 ± 1.3	**	I>II, I>III
	Left	5.3 ± 1.4	4.4 ± 0.9	4.1 ± 0.8	**	I>II, I>III
Hip joint abductor group (kgf)	Right	7.9 ± 3.3	6.4 ± 3.2	5.7 ± 2.7	**	I>II, I>III, II>III
	Left	7.2 ± 3.5	5.9 ± 2.8	5.0 ± 2.0	**	I>II, I>III
Hip joint adductor group (kgf)	Right	7.9 ± 3.1	6.6 ± 3.1	6.0 ± 2.9	**	I>II, I>III
	Left	7.2 ± 3.2	5.9 ± 2.5	5.4 ± 2.0	**	I>II, I>III
Knee joint flexor group (kgf)	Right	6.7 ± 2.7	5.4 ± 2.5	4.8 ± 2.2	**	I>II, I>III, II>III
	Left	6.4 ± 2.6	5.0 ± 2.2	4.7 ± 1.9	**	I>II, I>III
Knee joint extensor group (kgf)	Right	9.5 ± 3.1	8.0 ± 2.9	7.2 ± 2.7	**	I>II, I>III, II>III
	Left	8.6 ± 3.2	7.1 ± 2.7	6.3 ± 2.3	**	I>II, I>III, II>III
Ankle joint dorsiflexor group (kgf)	Right	6.9 ± 2.7	6.2 ± 2.7	6.0 ± 2.7	**	I>II, I>III
	Left	6.5 ± 2.0	5.7 ± 1.8	5.4 ± 1.7	**	I>II, I>III
Ankle joint plantar flexor group (kgf)	Right	9.6 ± 4.0	8.0 ± 3.2	7.0 ± 2.8	**	I>II, I>III
	Left	9.5 ± 4.0	7.8 ± 3.3	6.7 ± 2.6	**	I>II, I>III, II>III
Grip strength (kg)	Right	16.4 ± 7.7	15.4 ± 7.8	15.3 ± 7.7	**	I>II, I>III
	Left	14.9 ± 7.1	14.2 ± 7.0	13.8 ± 6.8	**	I>II, I>III
Circumference of thigh at 15 cm from patella (cm)	Right	42.3 ± 5.3	42.6 ± 5.1	42.2 ± 5.0	*	II>III
	Left	41.6 ± 4.6	41.6 ± 4.2	41.4 ± 4.3	n.s	
Circumference of thigh at 10 cm from patella (cm)	Right	38.8 ± 4.9	39.1 ± 4.9	38.7 ± 4.8	n.s	
	Left	38.3 ± 4.2	38.5 ± 4.2	38.3 ± 4.2	n.s	
Circumference of thigh at 5 cm from patella (cm)	Right	35.6 ± 4.3	35.6 ± 4.3	35.0 ± 4.3	**	I>III, II>III
	Left	35.6 ± 3.9	35.4 ± 3.9	34.7 ± 4.0	**	I>III, II>III
Maximum count of rising-from-chair motion		22.1 ± 10.4	16.6 ± 9.3	14.6 ± 8.2	**	I>II, I>III
Maximum count of rising-from-chair motion in 10 seconds		4.4 ± 1.4	3.8 ± 1.1	3.2 ± 0.8	**	I>II, I>III, II>III
Maximum count of upper limb elevation		30.6 ± 14.9	26.5 ± 14.3	23.7 ± 12.7	**	I>II, I>III, II>III
Maximum count of upper limb elevation in 10 seconds		5.8 ± 1.3	5.5 ± 1.3	5.0 ± 1.2	**	I>III, II>III
10 m walking time (sec)	Right	13.5 ± 4.1	14.9 ± 4.8	15.9 ± 5.1	**	I<II, I<III
Number of steps in 10 m	Left	25.0 ± 6.2	26.6 ± 7.6	28.9 ± 7.9	**	I<III, II<III
FRT (cm)	Right	16.8 ± 4.0	14.5 ± 4.0	12.8 ± 3.3	**	I>II, I>III, II>III
	Left	16.4 ± 3.8	14.2 ± 3.9	12.4 ± 3.6	**	I>II, I>III, II>III
TUGT (sec)	Right	15.3 ± 5.5	18.3 ± 6.9	19.9 ± 7.0	**	I<II, I<III, II<III
	Left	15.5 ± 6.3	18.6 ± 7.4	20.4 ± 7.3	**	I<II, I<III, II<III

*p<0.05, **p<0.01

Regarding knee joint extensor group, significant increases were observed in the intervention group for both sides. Right extensor strength changed from 7.0 ± 2.3 kgf to 11.6 ± 3.0 kgf and 12.0 ± 3.0 kgf with rates of change of 74.9% and 82.4%, and left extensor strength changed from 6.8 ± 2.3 kgf to 10.8 ± 2.6 kgf and 11.5 ± 2.9 kgf with rates of change of 69.5% and 80.8%. While, significant decreases were observed in the control group for both sides. Right extensor strength changed from 9.5 ± 3.1 kgf to 8.0 ± 2.9 kgf and 7.2 ± 2.7 kgf with rates of change of –15.8% and –24.5%, and left extensor strength changed from 8.6 ± 3.2 kgf to 7.1 ± 2.7 kgf and 6.3 ± 2.3 kgf with rates of change of –16.8% and –25.8%. There were significant differences between both groups in the rates of change of right and left.

4) Ankle joint dorsiflexor and plantar flexor

Regarding ankle joint dorsiflexor group, significant increases were observed in the intervention group for both sides. Right dorsiflexor strength changed from 4.6 ± 1.6 kgf to 7.2 ± 1.8 kgf and 7.4 ± 2.1 kgf with rates of change of 67.2% and 68.9%, and left dorsiflexor strength changed from 4.4 ± 1.1 kgf to 6.8 ± 1.8 kgf and 6.9 ± 2.1 kgf with rates of change of 58.5% and 59.9%. While, significant decreases were observed in the control group for both sides. Right dorsiflexor strength changed from 6.9 ± 2.7 kgf to 6.2 ± 2.7 kgf and 6.0 ± 2.7 kgf with rates of change of –9.4% and –13.9%, and left dorsiflexor strength changed from 6.5 ± 2.0 kgf to 5.7 ± 1.8 kgf and 5.4 ± 1.7 kgf with rates of change of –11.7% and –17.2%. There were significant differences between both groups in the rates of change of right and left.

Regarding ankle joint plantar flexor group, significant increases were observed in the intervention group for both sides. Right flexor strength changed from 4.9 ± 1.3 kgf to 11.7 ± 3.9 kgf and 13.7 ± 5.3 kgf with rates of change of 140.7% and 180.3%, and left flexor strength changed from 4.6 ± 1.2 kgf to 12.0 ± 4.0 kgf and 13.6 ± 5.3 kgf with rates of change of 164.4% and 198.7%. While, significant decreases were observed in the control group for both sides. Right flexor strength changed from 9.6 ± 4.0 kgf to 8.0 ± 3.2 kgf and 7.0 ± 2.8 kgf with rates of change of –16.7% and –25.8%, and left flexor strength changed from 9.5 ± 4.0 kgf to 7.8 ± 3.3 kgf and 6.7 ± 2.6 kgf with rates of change of –17.2% and –27.6%. There were significant differences between both groups in the rates of change of right and left.

Change in grip strength

Regarding grip strength, significant increases were observed in the intervention group for both sides. Right grip strength changed from 16.2 ± 5.9 kg to 18.0 ± 5.2 kg and 17.8 ± 5.2 kg with rates of change of 15.4% and 13.7%, and left grip strength changed from 14.0 ± 4.4 kg to 16.1 ± 4.3 kg and 15.9 ± 4.4 kg with rates of change of 17.6% and 15.6%. While, significant decreases were observed in the control group for both sides. Right grip strength changed from 16.4 ± 7.7 kgf to 15.4 ± 7.8 kgf and 15.3 ± 7.7 kgf with rates of change of –7.2% and –8.1%, and left grip strength changed from 14.9 ± 7.1 kgf to 14.2 ± 7.0 kgf and 13.8 ± 6.8 kgf with rates of change of –5.6% and –8.0%. There were significant differences between both groups in the rates of change of right and left.

Change in circumference of the thighs

Regarding circumference of the thighs, significant differences were observed in the intervention group for all the circumferences excluding those of the right thigh at 5 cm and 10 cm from the patella. Circumference of the right thigh at 15 cm from the patella changed from 42.7 ± 3.9 cm to 43.5 ± 4.4 cm and 43.4 ± 4.4 cm with rates of change of 2.0% and 1.7%, and the left counterpart changed from 42.3 ± 4.1 cm to 43.1 ± 4.2 cm and 43.0 ± 4.3 cm with rates of change of 2.0% and 1.8%. Circumference of the right thigh at 10 cm from the patella changed from 39.6 ± 3.7 cm to 40.1 ± 4.0 cm and 40.0 ± 4.1cm with rates of change of 1.2% and 0.9%, and the left counterpart changed from 39.3 ± 3.8 cm to 39.9 ± 3.8 cm and 39.7 ± 3.9 cm with rates of change of 1.5% and 1.1%. Circumference of the right thigh at 5 cm from the patella changed from 36.2 ± 3.7 cm to 36.7 ± 3.8 cm and 36.7 ± 4.0 cm with rates of change of 1.3% and 1.3%, and the left counterpart changed from 36.2 ± 3.7 cm to 36.6 ± 3.6 cm and 36.5 ± 3.8 cm with rates of change of 1.3% and 1.0%.

While, significant differences were observed in the control group for all the circumferences excluding those of the left thigh at 15 cm and both thighs at 10 cm from the patella. Circumference of the right thigh at 15 cm from the patella changed from 42.3 ± 5.3 cm to 42.6 ± 5.1 cm and 42.2 ± 5.0 cm with rates of change of 0.9% and –0.1%, and the left counterpart changed from 41.6 ± 4.6 cm to 41.6 ± 4.2 cm and 41.4 ± 4.3 cm with rates of change of 0.2% and –0.3%. Circumference of the right thigh at 10 cm from the patella changed from 38.8 ± 4.9 cm to 39.1 ± 4.9 cm and 38.7 ± 4.8 cm with rates of change of 0.6% and –0.3%, and the left counterpart changed from 38.3 ± 4.2 cm to 38.5 ± 4.2 cm and 38.3 ± 4.2 cm with rates of change of 0.4% and –0.2%. Circumference of the right thigh at 5 cm from the patella changed from 35.6 ± 4.3 cm to 35.6 ± 4.3 cm and 35.0 ± 4.3 cm with rates of change of 0.2% and –1.6%, and the left counterpart changed from 35.6 ± 3.9 cm to 35.4 ± 3.9 cm and 34.7 ± 4.0 cm with rates of change of –0.7% and –2.5%.

There were significant differences between both groups in the rate of change at 3 months of the left thigh circumference at 5 cm, and that at 6 months of both thighs' circumferences at 5 and 15 cm.

Changes in maximum count of continuous repetition and maximum count in 10 seconds of rising-from-chair motion

Regarding changes in maximum count of continuous repetition of the rising-from-chair motion, significant increases were observed in the intervention group from 25.6 ± 17.7 to 44.7 ± 28.7 and 52.0 ± 29.1 with rates of change of 86.0% and 124.3%. While, significant decreases were observed in the control group from 22.1 ± 10.4 to 16.6 ± 9.3 and 14.6 ± 8.2 with rates of change of –23.9% and –32.7%. There were significant differences between both groups in the rates of change.

Regarding the maximum count of the rising-from-chair motion in 10 seconds, significant increases were observed in the intervention group from 4.5 ± 1.1 to 4.9 ± 1.0 and 5.0 ± 1.3 with rates of change of 10.9% and 12.3%. While, significant decreases were observed in the control group from 4.4 ± 1.4 to 3.8 ± 1.1 and 3.2 ± 0.8 with rates of change of –11.1% and –23.3%. There were significant differences between both groups in the rates of change.

Changes in maximum count of continuous repetition and maximum count in 10 seconds of upper limb elevation motion

Regarding changes in maximum count of continuous repetition of upper limb elevation motion, significant increases were observed in the intervention group from 35.9 ± 20.4 to 64.3 ± 35.5 and 71.0 ± 35.1 with rates of change of 90.0% and 123.7%. While, significant decreases were observed in the control group from 30.6 ± 14.9 to 26.5 ± 14.3 and 23.7 ± 12.7 with rates of change of –14.0% and –23.8%. There were significant differences between both groups in the rate of change.

Regarding maximum count of upper limb elevation motion in 10 seconds, significant increases were observed in the intervention group from 6.3 ± 1.7 to 7.7 ± 1.6 and 7.6 ± 1.6 with rates of change of 27.4% and 26.7%. While, significant decreases were observed in the control group from 5.8 ± 1.3 to 5.5 ± 1.3 and 5.0 ± 1.2 with rates of change of –3.6% and –13.1%. There were significant differences between both groups in the rates of change.

Changes in 10 m walking time and number of steps

Regarding 10 m walking time, significant decreases were observed in the intervention group from 12.5 ± 5.3 seconds to 11.3 ± 4.9 seconds and 11.8 ± 5.3 seconds with rates of change of –8.1% and –4.8%. While, significant increases were observed in the control group from 13.5 ± 4.1 seconds to 14.9 ± 4.8 seconds and 15.9 ± 5.1 seconds with rates of change of 10.6% and 18.2%. There were significant differences between both groups in the rate of change.

Regarding the number of steps in 10 m, significant decreases were observed in the intervention group from 24.2 ± 8.1 steps to 23.1 ± 8.5 steps and 23.7 ± 9.3 steps with rates of change of –4.4% and –2.6%. While, significant increases were observed in the control group from 25.0 ± 6.2 steps to 26.6 ± 7.6 steps and 28.9 ± 7.9 steps with rates of change of 6.2% and 15.7%. There were significant differences between both groups in the rates of change.

Changes in FRT

Regarding FRT, significant increases were observed in the intervention group for both sides. FRT in the right side changed from 18.6 ± 6.5 cm to 22.0 ± 5.9 cm and 20.7 ± 5.7 cm with rates of change of 25.0% and 16.4%, and that in the left side changed from 18.2 ± 5.1 cm to 21.3 ± 4.6 cm and 20.5 ± 4.8 cm with rates of change of 23.5% and 18.1%. While, significant decreases were observed in the control group for both sides. FRT in the right side changed from 16.8 ± 4.0 cm to 14.5 ± 4.0 cm and 12.8 ± 3.3cm with rates of change of –13.6% and –23.4%, and that in the left side changed from 16.4 ± 3.8 cm to 14.2 ± 3.9 cm and 12.4 ± 3.6 cm with rates of change of –13.6% and –24.9%. There were significant differences between both groups in the rates of change of right and left.

Changes in TUGT

Regarding TUGT, significant decreases were observed in the intervention group for both clockwise and counter-clockwise rotations. TUGT by clockwise rotation changed from 14.3 ± 4.7 seconds to 13.1 ± 5.2 seconds and 13.0 ± 5.6 seconds with rates of change of –9.6% and –11.3%, and that by counter-clockwise rotation changed from 14.3 ± 5.2 seconds to 13.1 ± 5.6 seconds and 13.1 ± 5.9 seconds with rates of change of –9.4% and –9.8%. While, significant increases were observed in the control group for both rotational directions. TUGT by clockwise rotation changed from 15.3 ± 5.5 seconds to 18.3 ± 6.9 seconds and 19.9 ± 7.0 seconds with rates of change of 19.3% and 30.8%, and that by counter-clockwise rotation changed from 15.5 ± 6.3 seconds to 18.6 ± 7.4 seconds and 20.4 ± 7.3 seconds with rates of change of 20.5% and 34.4%. There were significant differences between both groups in the rates of change of both rotational directions.

DISCUSSION

This study verified the effect of an intervention by an exercise program which aimed to improve physical functions in the over 75s. Specifically, upper limb elevation exercise with water-filled PET bottles and rising-from-chair exercise with gripping parallel bars were provided for upper and lower limbs, respectively, for six months. As a result, statistically significant improvements were observed in each assessment parameter in the intervention group.

Muscle group strength of elbow joint flexor and extensor, hip joint abductor and adductor, knee joint flexor and extensor, ankle joint dorsiflexor and plantar flexor increased significantly with p values of <5%. Also, grip strength significantly increased with p values of <5%. These results are considered to be the effects of combined motion training used in this study such as exercise of upper limbs as a whole with the use of PET bottles and a rising-from-chair exercise, instead of training for individual muscles. Also, comparison of the rate of change in the muscle strength by individual muscles in the intervention group revealed some characteristics in both upper and lower limbs. That is, among upper limb muscles, the rate of change of the right and left elbow joint flexor groups were greater at 61.0% and 51.7%, respectively, than that of right and left elbow joint extensor groups which were 39.3% and 34.4%. This difference was considered to be because the elbow joint flexor group tended to receive more load than the extensor groups due to the position of the upper limb continuously kept in an anti-gravitational position in addition to the weight of the PET bottle.

Fukunaga et al.[14, 15] compared the change of the mass of various muscle groups with age by measuring the thickness of the muscles by ultrasonography since muscle function correlates with the cross-sectional area. They found greater reduction in the muscle mass of the anterior side of the upper limb than the posterior side. They explained it is because, in the standing or sitting position, elbow flexion requires stronger muscle power than extension due to the anti-gravitational direction of the movement, and because biceps brachii, the prime mover of elbow flexion, has more chance to be used in various motions in daily life, including eating activity, and raising and transferring materials, contrary to triceps brachii which has less chance to exert power anti-gravitationally.

Among the lower limb muscles, the rates of change in the strength of right and left knee joint extensor group and right and left ankle joint plantar flexor group were greater than other lower limb muscle groups at 74.9%, 69.5%, 140.7%, and 164.4%, respectively. This is attributed to the result of focused reinforcement of quadriceps femoris and triceps surae by rising-from-chair motion in which the weight of the subject is applied as the load. Fukunaga[14, 15] described that the most effective exercises to reinforce lower limb muscle strength in the elderly is rising-from-chair or rising-from-bed exercises, and the ability of quick rising is the most important capacity in daily life for the elderly. He also said that rising-from-chair motion, which is repetition of the simple motion of standing up from the chair and sitting again, is highly safe without requiring excessive flexion and extension of hip and knee joints[16]. In addition, rising-from-chair motion in the intervention group of the present study improved both aspects of endurance and quickness, which is represented by the 86.0% improvement in maximum counts of continuous repetition and the 10.9% improvement in maximum count in 10 seconds. These results support the idea that regular exercise leads to improvement of both quickness and muscle strength in the elderly as mentioned by Fukunaga[14, 15], although quick motion which requires instantaneous force may cause injury since type I fiber (slow twitch fiber) is more greatly atrophied than type II fiber (fast twitch fiber) in the elderly in general[17–19].

The rate of change of circumference of the thigh in the intervention group was limited at an average of 1–2% at any point of either thigh. Ikai[20] described that there are two mechanisms of muscle strength reinforcement effect of exercise, that is, a neural mechanism which is represented by alteration of excitability of motor neurons and muscle alteration mechanism by muscular hypertrophy, and that the former mechanism is dominant in the elderly. In this study, however, muscular reinforcement observed in the intervention group appeared to be more attributable to the neural mechanism, since the strength of each muscle group was remarkably improved while increase in the circumference of the thigh was limited to 1–2%.

Regarding the balancing ability of the elderly, Ishihara[21)] reported that the percentage of people who experienced falls in a year among residents of nursing homes which take fall preventive measures is 14%, and among them about 45% repeatedly experienced falls. He concluded that important factors for the elderly to prevent falls and accidents in their daily life are maintenance and enhancement of physical strength in the technical aspects to adjust and control motions functionally, including balancing ability, alertness, and coordination. Besides, he noted that, among various risk factors of falls, declines in balancing function, muscle strength, and posture adjusting ability, and especially decline in dynamic balancing function required for walking and posture change as well as decline in lower leg muscle strength can be improved by regular exercise, which may eventually lead to fall prevention. In this study, FRT was used to assess balancing ability, and TUGT[22)] and 10 m walking speed and number of steps were also assessed as combined motions which are strongly related to balancing. FRT is a balance evaluation method in the standing position[24)] developed by Duncan et al.[23)], in which the distance of the reach when an upper limb is extended as far forward as possible while maintaining the supporting basal surface of standing. It is said that those with FRT of 15 cm or less have higher risk of falls[25, 26)].

In the intervention group, the rate of change of FRT was remarkable at 25.0% and 23.5% on the right and left sides, respectively, and the rate of change of TUGT was –9.6% and –9.4% for clockwise and counter-clockwise rotations, respectively. Also, the rates of change of 10 m walking time and number of steps were –8.1% and –4.4%. Although this study did not examine the history of falls, no subject in the intervention group experienced a fall within the 6 months after the start of the program. This is considered to be because the rising-from-chair exercise reinforced muscle strength of lower limb as a whole through improvement of strength of abductor and adductor group of the hip joint as well as flexor and extensor groups of hip and knee joints, leading to improvement of lower limb stability. In addition, repetition of standing and sitting motion improved dynamic balance.

The rate of change of each parameter was remarkable in the first 3 months, but less so in the next 3 months, or from 3 months to 6 months after the start of the program, except for strength of ankle joint plantar flexor group, maximum count of continuous repetition of rising-from-chair motion, and maximum count of continuous repetition of upper limb elevation, all of which showed great improvement.

FRT was increased in the first 3 months but decreased after that, and the time and number of steps for 10 m walking was continuously improved.

Lord et al.[27)] write that balance is maintained in coordination of various systems including muscle strength, sense of vision, neuromuscular adjustment, vestibular sense, peripheral sensation, and reaction time, and the functionality of these system declines with aging.

Since FRT increased in the first 3 months but decreased in the second 3 months in the intervention group despite maintenance and partial increase in the strength of lower muscle groups, there is a possibility that the factors other than muscle force such as neuromuscular adjustment, vestibular sense, and peripheral sensation were compromised due to aging.

Fujiwara[28)] reviewed the results of recent studies at home and abroad, and discussed exercise programs for improving balance ability of the elderly. According to his review, exercise programs which combined muscle training and balancing training are more effective at improving balancing ability, while those with low load intensity which utilize rising-from-chair and clime-up-and-down motions are useful for the maintenance of balancing ability, and it is important for health care providers to provide a program being aware that execution of exercise or motion always accompanies balance maintenance issues. Therefore, we believe that there is a possibility to maintain and improve balancing ability further by combining a program that aims at maintaining and improving balancing ability with the program of this study.

Contrary to the intervention group which showed a remarkable effect of the exercise program, the control group showed a remarkable decline in most assessment parameters, especially regarding the rate of change in muscle strength, and significant reduction was observed in the lower limbs rather than the upper limbs. Also, maximum count of continuous repetition of the rising-from-chair motion, which is influenced by the physical capacity of the lower limbs, decreased significantly, and TUGT significantly increased. These results are considered to be the result of a rapid decline in anti-gravitational muscle strength mainly of the lower limbs, due to disuse factors of insufficient exercise or decreased activity, in addition to the aging effects. Since decline in muscle strength and physical capacity causes bad posture, pain in the lower back and knee, and falls, which may lead to a bed-ridden condition, it would appear to be indispensable for the elderly to perform regular exercise to live a healthy daily life.

This study verified the benefits of long-term continuation of relatively simple, easy, safe, and low load exercises, which are composed of muscle strength, muscle endurance, alertness, balancing ability, flexibility, and physical endurance such as rising-from-chair exercise and upper limb elevation exercise with the use of water-filled PET bottles, for the maintenance and improvement of physical capability and physical strength in the over 75s. Even for the old old, exercise programs including muscle training are useful for the maintenance and improvement of amount of daily life activities and QOL, and these should be actively utilized clinically. Besides, we believe utilization of balance training in addition to the exercise program of this study would contribute to further maintenance and improvement of balancing ability.

With aging, however, the possibility of having other complications becomes higher, and the response to them is diverse. In order to establish effective measures, it is indispensable to establish evidence based physical therapy (EBPT) and to further advance studies in the future.

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