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Effect of Long-Term Exercise on Physical Function and Medical Examination in Elderly Women

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The objective of this study was to evaluate the effects of exercise on physical functions (activities of daily living, physical fitness) and medical examination parameters as risk factors for lifestyle-related diseases in 65- to 75-year-old women living independently at home. The women were provided instruction on aerobic exercises and resistance training for 20 weeks. This was followed by a voluntary continuation of the exercises for 3 years (140 weeks). The subjects included 69 women who participated in an exercise instruction program in a fitness class. Thirty-eight of the women voluntarily continued with the exercise program [exercise (EX) group] and 31 women did not [sedentary (SED) group]. A control group of 44 women was also established. In the control group, most of the physical function parameters tended to deteriorate after 160 weeks. The medical examination parameters also tended to worsen, with many values above the normal limits. In the EX group, however, the physical function actually improved after 160 weeks. The improved control of hypertension, hyperlipidemia and hyperglycemia was also observed. In the SED group, physical function improved after 20 weeks of exercise instruction but began to deteriorate once exercise was stopped. These results suggest that exercise instruction and continued exercise programs, based on an appropriate exercise prescription, are effective in improving physical function and controlling the risk factors for lifestyle-related diseases in elderly women living at home.

Key words: activities of daily living; elderly woman; exercise prescription; physical function; quality of life

Health assessment of elderly people must include both medical examination results and the ability of the person's functional capacity in daily activities (World Health Organization, 1984). In the elderly, who often have multiple chronic disorders, the focus must not be exclusively on medical evaluation parameters. A broader perspective must be considered to improve the quality of life (QOL) for each person. This includes controlling risk factors for chronic diseases and maintenance of physical function to continue daily activities (Roberts et al., 1994; Ohta et al., 2001). Such an approach seems to contribute to self-support of elderly people and a longer, healthier life. The evaluation of activities of daily living (ADL) is useful in assessing the ability to function independently. Methods of evaluating ADL include the use of questionnaires (Lowton, 1963; Mahoney and Barthel, 1965; Demura et al., 2000) and combined testing with simulations of ADL (e.g., a sitting and standing up test, a zigzag walking test, a hand working test with a pegboard for dexterity evaluation, and a rope working test for

Abbreviations: ADL, activities of daily living; BMI, body mass index; CA, chronological age; ECG, electrocardiograph; EX, exercise; HDLC, high-density lipoprotein cholesterol; HFA, health-related fitness age; LDLC, low-density lipoprotein cholesterol; QOL, quality of life; SBP, systolic blood pressure; SED, sedentary; TC, total cholesterol; TG, triglycerides; $\dot{V}O_2max$, maximal oxygen uptake self-care evaluation) (Oida et al., 1996). From the viewpoint of health-related physical fitness, the factors of physical fitness for performance (cardiorespiratory fitness, muscular strength, muscular endurance and flexibility) are important parameters (American Alliance for Health, Physical Education, Recreation and Dance, 1980; MiSook et al., 1996).

The aging process in older individuals is associated with a loss of muscle strength and a decrease in muscle cross-sectional area. If this process were irreversible, an elderly person increasing functional capacity and maintaining ADL function through exercise and training would be impossible. However, studies on muscle morphology and function in the elderly have been positive in this regard; for example, even the selective atrophy of fast muscle fibers with aging may be due to a relative lack of daily activity and a reduced demand on the muscles (Aniansson et al., 1983). Other studies show that long-term training for 50 weeks by women in their 70s causes thigh muscle hypertrophy (Cress et al., 1991) and that the recovery of muscle function and hypertrophy occur readily in elderly males (Aniansson et al., 1984). These findings suggest that training can enhance physical fitness even in elderly individuals.

Improved physical fitness can prevent or reverse a decline in ADL function that is often associated with aging. This fact is supported by the results of several studies (Larsson, 1982; Frontera et al., 1988). Healthy lifestyle habits, with an emphasis on exercise, help to maintain or improve ADL function. However, further research is needed to establish the protocols for prescribing exercise and to determine optimum duration for exercise. The studies to date, for example, have not fully evaluated the long-term effects of combining aerobic exercise and resistance training. In particular, there has been a lack of research on the effects of training for muscle strength and endurance in elderly females, who may be more susceptible to some pathologic conditions than males. Females are weaker than males at all ages, and the incidence of falls and hip fractures in females is 2 to 3 times that of males (Cook et al., 1982). The ability of these women to function independently is closely related to ADL function.

The present study investigated the long-term effects of physical training in elderly females. The effects of fitness training were evaluated with an emphasis on exercise and its importance in long-term health management.

Subjects and Methods

Subjects

We initially enrolled a total of 125 elderly women living independently at home. Based on examination by a physician, each of the women completing the study was free of orthopedic, neuromuscular, cardiovascular, pulmonary and chronic diseases. In order to ensure the safety during the exercises and to positively confirm their effect of the exercise, the subjects taking the following were excluded: steroids (including estrogen) and cardiac stimulants, and medication for angina pectoris, hypertension, hyperlipidemia, diabetes and arrhythmia. As a result, 12 of the women were excluded from analysis. The remaining 113 women (age, 67. 8 ± 4. 4 years, mean ± SD; range, 65 to 75 years) were divided into the fitness class participation group (69 women) and a control group (44 women) according to whether the person can participate in the fitness class. However, there were no significant differences between the fitness class participants and the control group in age, fitness and examination parameters. Also, no differences were found between the 2 groups in terms of academic background, occupation and morbidity.

Based on a follow-up survey after the fitness class was completed, the fitness class group was further divided into those who continued to exercise on their own [exercise (EX) group: 38 women] and those who did not [sedentary (SED) group: 31 women]. Concerning occupation, lifestyle and morbidity among the 3 groups (control group, EX group and SED group) there were some slight differences. Details of the study were explained to all the subjects and a consent was obtained. The study began in May 1997 and ended in May 2001.

Performance testing and medical examination

All subjects underwent performance testing and a medical examination at the start of the study. The performance testing included assessment of ADL function (Meiji Health and Physical Fitness Research Institute: e.g., a sitting and standing up test, a zigzag walking test, a hand working test with a pegboard for dexterity evaluation and a rope working test for self-care evaluation) (Oida et al., 1996) and a health-related physical fitness evaluation. The latter included an assessment of grip strength as muscle strength for the static muscle strength index (Grip-D, Takei Kiki Kogyo, Tokyo, Japan), leg extension power as an index to leg muscle power output which is similar to the load experienced in daily life (isokinetic leg extension power measurement device, fixed speed 80 cm/s, Takei Kiki Kogyo) (Ito and Yoda, 1992), side stepping as an index to neuro-muscle coordination and agility (distance between lines, 80 cm), forward body bending in a sitting position as a flexibility test which is related to backache (Ministry of Education, Culture, Sports, Science and Technology physical fitness guidelines), balance with the eyes closed while standing as an equilibrium test which is related to instability and falls (GS-200HIV Statokinesogram, Anima Corp., Tokyo), a rhythm step test for estimating maximum oxygen consumption ($\dot{V}O_2max$) as an index to cardiorespiratory fitness (Hatano et al., 1995) and the number of steps walked each day as measured by a pedometer (Mampokei ET-450, Yamasa Tokei Keiki, Tokyo) as an index to the amount of daily physical activity (Hatano et al., 1995).

The following medical examinations were carried out. For blood tests, total cholesterol (TC), high-density lipoprotein cholesterol (HDLC), low-density lipoprotein cholesterol (LDLC), triglycerides (TG), fasting plasma glucose, Hb and hematocrit were adopted from the results of periodical health examinations by the local government during the year. Body mass index (BMI) was measured using height (m) and weight (kg). The percentage of body fat was calculated by bioelectrical impedance analysis (Sakamoto et al., 1992). Systolic blood pressure (SBP) while resting was measured with a mercurical sphygmomanometer. A 17-cm 2-step exercise electrocardiographic (ECG) stress test (rate, 60 times/min) was also performed.

The above testing at the baseline (start of study) allowed the assessment of the suitability (safety risk and potential effect) of the exercise program in each subject. Repeat testing was performed at the end of the physical fitness class (20 weeks) and the end of the voluntary exercise period (140 weeks) to evaluate the effects of exercising.

Exercise prescription and training protocol

The results of the physical fitness testing and medical examination at the baseline were used to establish an exercise program for each subject. The exercise prescription included aerobic exercise (walking) and resistance training (with dumbbells or tubing) (Table 1). The intensity

Table 1. Exercise prescription in the fitness program

Aerobic exercise	Type of exercise	Walking (slow walk–fast walk)
	Intensity of exercise	50% $\dot{V}O_2max$ and under arrhythmia appearance
	Frequency of exercise	5 times/week
	Duration of exercise	30 min
	Amount of exercise	300 kcal/day
Resistance exercise	Type of exercise	Exercise by rubber tube or dumbbell; 10 kinds of motion in the trunk, legs and arms
	Intensity of exercise	30–40% of maximum strength (20–30 repetition maximum)
	Frequency of exercise	3 times/week

of the aerobic exercise was set to 50% $\dot{V}O_2max$ as determined by the rhythm step test. The exercise included slow walking and fast walking for 30 min (2500–4000 steps) 5 times/week. This resulted in each woman walking more than a total of 10,000 steps daily, with an energy expenditure in excess of 300 kcal/day.

The intensity of the resistance training was set at 30–40% of the maximum muscle strength (20–30 repetition maximum). Two sets of 10 types of motions were performed 3 times/week. Each subject was free to use either dumbbells or tubing. Instruction was also given on stretching for "warming up" and "cooling down" before and after exercising.

Instruction for this aerobic-resistance exercise program was given for 20 weeks in the fitness class. Performance testing was done at the completion of the fitness class, with modification of the exercise prescription made as necessary. Each woman was requested to voluntarily continue the exercise program, including any modifications, for 140 weeks after the fitness class was completed. The overall rate of attendance in the fitness class was 86%. Of these 69 subjects, 31 (44%) continued the exercise program after the class.

Statistical analysis

Statistical analysis was performed using SAS software (SAS Institute, Tokyo). ADL function and physical fitness data at the end of the fitness class (20 weeks) and at the end of the voluntary exercise program period (160 weeks) were compared to the baseline data. The data for women with the medical examination parameter values exceeding the normal limits were also compared with the data after 160 weeks. A *t*-test was used to expose any statistical significant differences, at a level of $P < 0.\ 05$.

A correlation matrix of all 25 variables at the baseline was determined, and a factor analysis (after varimax orthogonal rotation) was applied to identify factors for elderly women with respect to physical function. The variables for each factor with absolute high loading values ($r > 4.\ 00$) were selected for the factor representation. A multiple regression formula was calculated using the factor representations as explanatory variables and chronological age (CA) as a target variable (i.e., a multiple regression formula using a standardized regression coefficient and explanatory variables where the *t*-test for regression coefficients satisfies a value of $P < 0.05$) using the same method used in a previous study (Kato et al., 2000).

Results

Subject characteristics

Average age was 66.9 ± 6.1 years in the control group, 67.5 ± 4.4 years in the fitness class participants (67.8 ± 4.5 years in the EX group, and 67.1 ± 4.1 years in the SED group). Tables 2 and 3 show ADL function and physical fitness test data. No significant differences in the baseline values were observed between the groups studied. The distribution of the measured values, which included averages and SDs, was similar to the mean values in the comparable age groups. The number of steps/day, an indicator of daily activity level, was about 7000 in each group. This approximates the mean value for adult women in "Health Japan 21: a guideline for national health promotion in the 21 century by the Ministry of Health and Welfare" (Health Japan 21 Planning Association, 2000), validating the mean ADL function and physical fitness parameter values; that is, the women in each group at the baseline were similar to other women of the same age range in the general population.

Table 4 shows the selected medical examination parameters for each group. No significant differences in any baseline values were observed among the groups. There are many people who show the values in which TC, SBP, fasting plasma glucose and BMI were higher than the reference values. However, the elderly women in our study were not a unique group. The relatively high incidences of medical examination values exceeding the normal limits are typical risk factors for diseases in many elderly individuals (Krumholz et al., 1994).

Table 2. Changes in ADL function parameters and activity level

Group	Age (year)	Sitting and standing up (s)	Zigzag walking (s)	Hand working (s)	Rope working (s)	Steps/day (step)
Control group [44]						
Baseline	66.9 ± 6.1	5.8 ± 2.6	7.0 ± 1.4	34.6 ± 3.1	6.8 ± 1.9	7310 ± 2105
160 weeks	70.7 ± 6.4	6.2 ± 2.3	7.3 ± 1.5	35.2 ± 3.0	7.1 ± 1.8	6823 ± 2238
Change		+0.4 ± 0.6*	+0.3 ± 0.4*	+0.6 ± 0.9*	+0.3 ± 0.5*	–487 ± 1215*
Participants in the fitness class [69]						
Baseline	67.5 ± 4.4	5.9 ± 2.5	7.0 ± 1.2	34.8 ± 3.8	6.8 ± 1.8	7022 ± 2045
160 weeks	71.3 ± 4.4	5.7 ± 2.1	6.8 ± 1.3	33.7 ± 3.6	6.3 ± 1.4	8123 ± 2106
Change		–0.2 ± 0.9	–0.2 ± 0.7	–1.1 ± 1.1	–0.5 ± 0.9	+1165 ± 2136
EX group [38] in the fitness class participants						
Baseline	67.8 ± 4.5	5.9 ± 2.9	7.0 ± 1.0	35.0 ± 4.4	6.8 ± 1.7	6969 ± 2212
20 weeks	68.4 ± 4.6	5.8 ± 1.9	6.8 ± 1.0	33.3 ± 2.9	5.9 ± 1.1	8188 ± 1877
160 weeks	71.6 ± 4.5	5.2 ± 1.6	6.4 ± 0.7	32.3 ± 3.7	5.8 ± 1.4	9005 ± 2001
Change		–0.7 ± 0.8*	–0.6 ± 0.6*	–2.7 ± 1.1*	–1.0 ± 0.8*	+2036 ± 1876*
SED group [31] in the fitness class participants						
Baseline	67.1 ± 4.1	5.8 ± 2.1	6.9 ± 1.3	34.5 ± 2.9	6.8 ± 1.8	7124 ± 1905
20 weeks	67.8 ± 4.0	5.8 ± 2.0	6.7 ± 1.3	33.2 ± 3.1	6.5 ± 1.4	7792 ± 1342
160 weeks	70.9 ± 4.2	6.2 ± 2.2	7.2 ± 1.3	34.9 ± 3.1	6.9 ± 1.5	7107 ± 1604
Change		+0.4 ± 0.6*	+0.3 ± 0.3*	+0.4 ± 0.9	+0.1 ± 0.3	–17 ± 238

Values expressed as mean ± SD.
EX, exercise; SED, sedentary.
[ ], number of subjects.
Change = 160-week value – baseline value.
* Significant change of 5% level.

Table 3. Changes in physical fitness parameters

Group	Grip strength (kg)	Leg power (W/kg)	Side steps (time)	Trunk flexion (cm)	Balance (cm^2)	$\dot{V}O_2max$ (mL/kg/min)
Control group [44]						
Baseline	24.1 ± 4.0	4.8 ± 2.0	29.0 ± 6.8	38.0 ± 8.9	3.9 ± 1.4	20.8 ± 3.3
160 weeks	23.7 ± 3.5	4.1 ± 1.9	26.8 ± 6.0	38.2 ± 8.5	4.5 ± 1.5	19.6 ± 3.2
Change	–0.4 ± 0.7	–0.7 ± 0.8*	–2.2 ± 1.2*	–0.2 ± 2.4	+0.6 ± 0.7*	–1.2 ± 0.9
Participants in the fitness class [69]						
Baseline	24.3 ± 5.5	4.8 ± 1.9	29.8 ± 6.9	38.5 ± 8.3	4.0 ± 1.5	20.2 ± 3.3
160 weeks	24.0 ± 4.5	5.1 ± 1.6	30.2 ± 6.8	39.1 ± 8.4	4.1 ± 1.6	20.0 ± 3.4
Change	–0.3 ± 0.7	+0.3 ± 1.0	+0.4 ± 2.6	+0.6 ± 2.5	+0.1 ± 0.6	–0.2 ± 2.3
EX group [38] in the fitness class participants						
Baseline	24.5 ± 5.9	4.9 ± 1.8	29.1 ± 6.5	38.2 ± 8.4	3.8 ± 1.5	19.9 ± 3.1
20 weeks	24.8 ± 5.9	5.4 ± 1.9	29.7 ± 6.4	39.5 ± 8.3	3.6 ± 1.7	21.8 ± 3.6
160 weeks	24.7 ± 4.5	5.9 ± 1.7	33.0 ± 5.8	40.6 ± 8.9	3.6 ± 1.3	23.3 ± 3.7
Change	+0.2 ± 0.3	+1.0 ± 0.9*	+3.9 ± 3.2*	+2.6 ± 2.6*	–0.2 ± 0.6	+3.4 ± 2.9*
SED group [31] in the fitness class participants						
Baseline	23.8 ± 3.6	4.7 ± 1.9	30.3 ± 7.6	38.6 ± 8.1	4.3 ± 1.6	20.6 ± 3.1
20 weeks	23.5 ± 3.6	5.4 ± 1.8	30.5 ± 8.6	39.0 ± 8.6	4.1 ± 1.7	20.8 ± 3.1
160 weeks	23.3 ± 3.6	4.2 ± 1.5	27.9 ± 5.8	38.1 ± 8.2	4.7 ± 1.7	19.2 ± 3.0
Change	–0.5 ± 1.3	–0.5 ± 0.4*	–2.4 ± 1.4*	–0.5 ± 2.3	+0.4 ± 0.5	–1.4 ± 1.9*

Values expressed as mean ± SD.
EX, exercise; SED, sedentary; $\dot{V}O_2max$, maximal oxygen uptake.
[ ], number of subjects.
Change = 160-week value – baseline value.
* Significant change of 5% level.

Table 4. Changes in medical examination parameters

Group	BMI (kg/m^2)	SBP (mmHg)	TC (mg/dL)	HDLC (mg/dL)	TG (mg/dL)	Plasma glucose (mg/dL)
Control group [44]						
Baseline	24.0 ± 4.0	136 ± 18	226 ± 35	54 ± 17	125 ± 62	97 ± 22
160 weeks	24.4 ± 4.1	138 ± 19	231 ± 39	51 ± 19	127 ± 61	99 ± 24
Change	+0.4 ± 2.1	+2 ± 4	+5 ± 11	–3 ± 4	+2 ± 9	+2 ± 7
Participants in the fitness class [69]						
Baseline	23.9 ± 4.1	136 ± 20	225 ± 37	53 ± 17	127 ± 61	96 ± 23
160 weeks	23.8 ± 3.9	134 ± 19	218 ± 36	55 ± 19	121 ± 60	95 ± 24
Change	–0.1 ± 2.5	–2 ± 7	–7 ± 12	+2 ± 6	–6 ± 10	–1 ± 5
EX group [38] in the fitness class participants						
Baseline	24.2 ± 4.2	138 ± 20	224 ± 38	53 ± 16	129 ± 62	95 ± 22
160 weeks	23.5 ± 3.8	130 ± 18	206 ± 31	61 ± 18	112 ± 59	90 ± 20
Change	–0.7 ± 2.8	–8 ± 8*	–18 ± 21*	+8 ± 7*	–17 ± 10*	–5 ± 6
SED group [31] in the fitness class participants						
Baseline	23.8 ± 3.9	134 ± 17	228 ± 36	53 ± 17	121 ± 62	98 ± 24
160 weeks	24.1 ± 4.0	136 ± 20	229 ± 41	52 ± 19	130 ± 60	98 ± 26
Change	+0.3 ± 2.0	+2 ± 5	+1 ± 4	–1 ± 4	+9 ± 11	+0 ± 3

Values expressed as mean ± SD.
[ ], number of subjects.
Change = 160-week value – baseline value.
BMI, body mass index; EX, exercise; HDLC, high-density lipoprotein cholesterol; SBP, systolic blood pressure; SED, sedentary; TC, total cholesterol; TG, triglycerides.
* Significant change of 5% level.

Effect of exercise on physical function parameters

The ADL function parameters shown in Table 2 (sitting and standing up test, zigzag walking test, hand working test with a pegboard for dexterity evaluation, and rope working test for self-care evaluation) are tests to assess the ability to perform specified maneuvers in a short period of time. The shorter times required to perform tasks therefore reflect improved function while longer times mean a decrease in function. The physical fitness parameters shown in Table 3 are, with the exception of balance, tests that measure strength, number of repetitions or distance. In these situations, the higher numbers mean improved performance. For balance function, stability is evaluated by measuring the area of motion away from the center of gravity. A lower number thus indicates improved function.

In the control group, the evaluation after 160 weeks demonstrated a significant deterioration in all ADL functions (Table 2). In addition, a significant decrease was observed in the number of steps/day (about 500) after 160 weeks. Physical fitness evaluation revealed a significant decrease in leg extension power, side steps, balance function and $\dot{V}O_2max$ (Table 3). However, among the fitness class participants, many fitness function parameters have the aspect of the improvement; the statistically significant change could not be recognized in either ADL functions and fitness parameters (Tables 2 and 3).

In the EX group, the evaluation after 160 weeks demonstrated a significant improvement in all ADL functions (Table 2). A significant increase was observed in the number of steps/day (about 2000). Physical fitness evaluation revealed a significant increase in those parameters (leg extension power, side steps, forward body bending and $\dot{V}O_2max$), with the

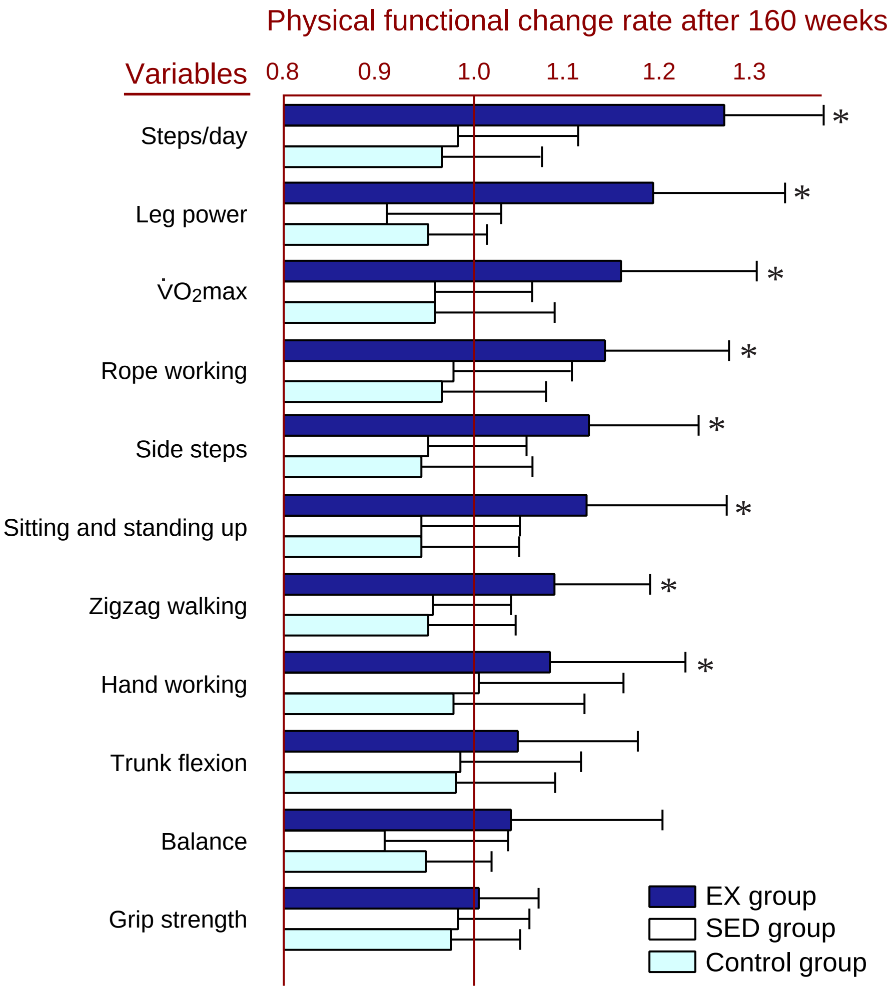

Fig. 1. Effect of long-term exercise on physical function variables. Change rate after 160 weeks, with baseline value as 1.0. Data arranged in order of magnitude of effect in the EX group. *Significant change of 5% level from baseline value. EX, exercise group; SED, sedentary group; $\dot{V}O_2max$, maximal oxygen uptake.

exception of grip strength and balance function (Table 3).

In the SED group, evaluation after 20 weeks revealed some improvement in ADL function and physical fitness parameters. After 160 weeks, however, a significant functional depression in sitting and standing up, and zigzag walking were observed (Table 2). Physical fitness evaluation demonstrated a significant decrease in leg extension power, side steps and $\dot{V}O_2max$ (Table 3). Figure 1 depicts the rates of change in physical function after 160 weeks with a relative baseline value of 1. 0 for each parameter. The items are shown in order starting with the highest rates of change in the EX group. The parameter with the largest change in the EX group was the total number of steps/day as an index to the amount of daily physical activity. A mean increase of 2000 steps/day was observed.

The parameter with the next highest rate of change was leg extension power. In the EX group, a significant increase of 20% (mean, 2.0 W/kg in body weight) from the baseline was observed. In the SED and control groups, leg extension power decreased by 10–15% (0.5–0.7 W/kg). The parameter with the next greatest change was $\dot{V}O_2max$ as evaluated by cardiores-

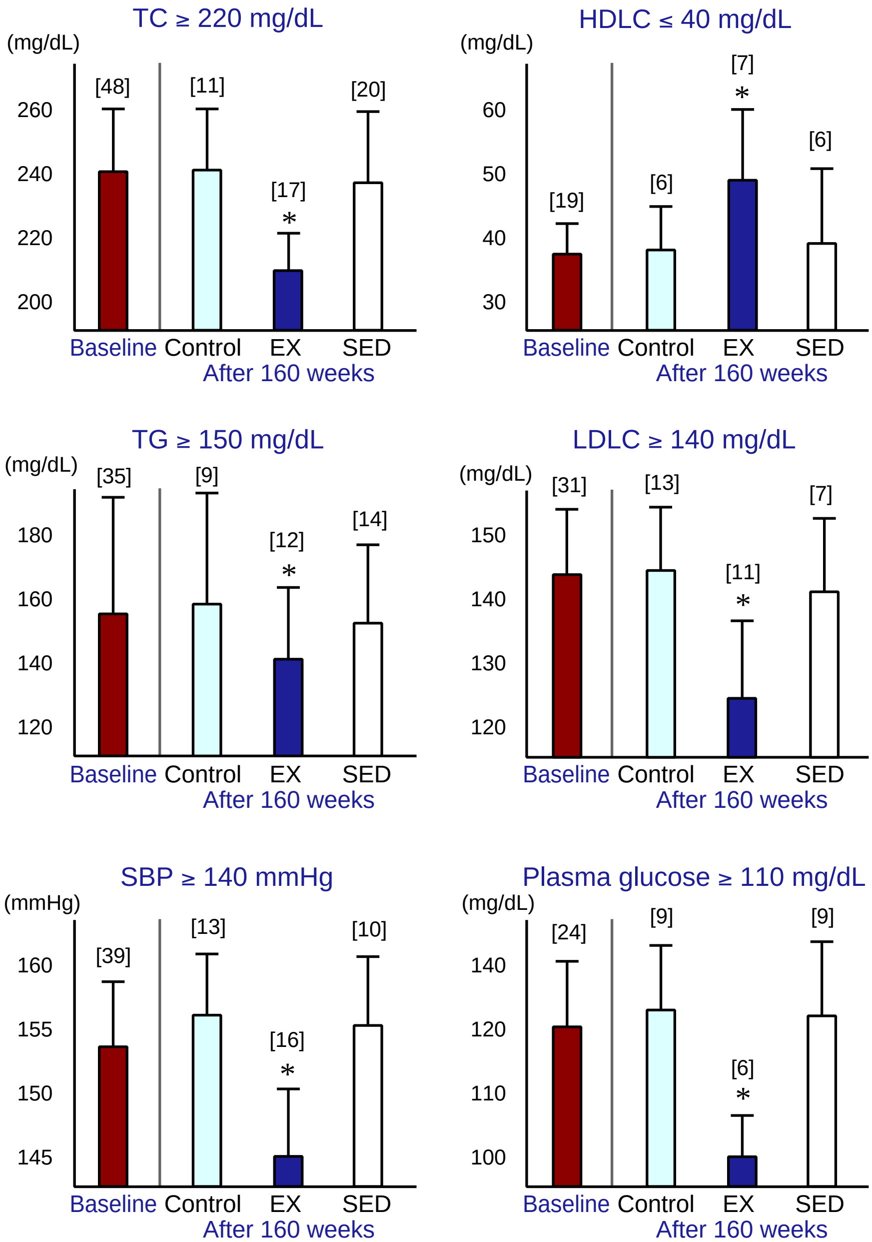

Fig. 2. Effect of long-term exercise on medical examination parameters. Change after 160 weeks was shown on persons who had deviated from the reference value in each group. *Significant change of 5% level from initial value. EX, exercise group; HDLC, high-density lipoprotein cholesterol; LDLC, low-density lipoprotein cholesterol; SBP, systolic blood pressure; SED, sedentary group; TC, total cholesterol; TG, triglycerides.

piratory fitness. In the EX group, the $\dot{V}O_2max$ significantly increased by 17% (3.4 mL/kg/min) from the baseline.

In the EX group, the ADL function parameters related to rope working for self-care, sitting and standing up, and zigzag walking demonstrated significant improvements from the baseline (8–15% improvements). No statistically significant changes were observed in balance function, hand working, forward body bending or grip strength.

Effect of exercise on medical examination parameters

In the control group, the evaluation of the BMI, SBP, serum lipids (TC, HDLC, TG) and fasting plasma glucose did not show any statistically significant changes (Table 4). The percentage of body fat, LDLC, Hb and hematocrit also did not show any statistically significant change. The incidence of abnormalities on the 2-step stress exercise ECG testing did not change from the baseline to 160 weeks (from 12% to 12%).

Among all of the fitness class participants, these medical examination parameter values did not change significantly. However, in the EX group, SBP, TC and TG significantly decreased, and the HDLC significantly increased (Table 4). The incidence of abnormalities on 2-step stress exercise ECG testing decreased significantly (from 12% to 6%). In the SED group, no statistically significant changes were observed in any of the medical examination parameter values (Table 4). The incidence of abnormalities on the 2-step stress exercise ECG testing decreased slightly (from 11% to 9%), but the difference was not statistically significant.

In order to evaluate the improvement in the medical examination parameters, not only the change of mean value, it is necessary to consider whether it improved in cases which deviated from the reference value. Figure 2 shows the changes after 160 weeks in cases which deviated from the reference value in each of the parameters in the 3 (control, EX, SED) groups.

The effects of exercising were evaluated in 48 women who had baseline TC levels higher than the reference value (220 mg/dL) (Fig. 2). Among these 48 subjects, 17 individuals of the EX group had a significant decrease of 26 ± 19 mg/dL that was observed in TC from the baseline. Eleven individuals of the control and 20 individuals of the SED group had a significant decrease. In addition, 35 women displayed baseline TG levels higher than the reference value (150 mg/dL). Among these 35 subjects, 12 individuals from the EX group had a significant decrease of 17 ± 10 mg/dL in the TG from the baseline.

Thirty-six women displayed baseline SBP levels higher than the reference value (140 mmHg). Their pathema was the 140–180 mmHg mild essential hypertention. Among these 36 subjects, 16 individuals of the EX group showed a significant decrease of 9 ± 8 mmHg in the SBP from the baseline. Nineteen women displayed baseline HDLC levels lower than the reference value (40 mg/dL). Among these 19 subjects, 7 individuals from the EX group showed a significant increase of 9 ± 7 mg/dL in the HDLC from baseline. A total of 31 women demonstrated baseline LDLC values above the reference value (140 mg/dL). Among these 31 subjects, 11 individuals from the EX group showed a significant decrease of 21 ± 19 mg/dL in the LDLC from the baseline. Furthermore, 24 women displayed baseline fasting blood glucose levels higher than the reference value (115 mg/dL). Among these 24 subjects, 6 individuals from the EX group showed a significant decrease of 16 ± 17 mg/dL in the fasting plasma glucose levels from the baseline.

Effect of exercise on health-related fitness age

A multiple regression formula was calculated using the factor representations as explanatory variables and CA as a target variable. The biological age, which differs from CA, was termed the health-related fitness age (HFA). The formula was as follows:

Table 5. Changes in HFA

Group	CA (year)	HFA (year)	Change (year)
Control group [44]			
Baseline	66.9 ± 6.1	66.1 ± 8.2	–0.8 ± 2.1
160 weeks	70.7 ± 6.4	69.3 ± 9.1	–1.4 ± 2.9
Participants in the fitness class [69]			
Baseline	67.5 ± 4.4	66.6 ± 7.8	–1.0 ± 3.1
160 weeks	71.3 ± 4.4	64.7 ± 8.9	–6.7 ± 6.8
EX group [38] in the fitness class participants			
Baseline	67.8 ± 4.5	66.6 ± 7.9	–1.2 ± 3.2
160 weeks	71.6 ± 4.5	60.9 ± 8.8	–10.7 ± 7.4*
SED group [31] in the fitness class participants			
Baseline	67.1 ± 4.1	66.5 ± 7.8	–0.7 ± 3.0
160 weeks	70.9 ± 4.2	68.2 ± 9.0	–2.8 ± 2.3

Values expressed as mean ± SD.
CA, chronological age; EX, exercise; HFA, health-related fitness age; SED, sedentary.
[ ], number of subjects.
Change = HFA – CA.
* Significant change of 5% level.

$$HFA = 84.3 + 0.734X_1 - 0.253X_2 - 0.920X_3 - 0.347X_4 + 0.633X_5 - 0.075X_6 + 0.0102X_7 + 0.0131X_8 - 0.133X_9 - 0.000561X_{10} \quad (1)$$

where X_1, sitting and standing up; X_2, grip strength; X_3, leg extension power; X_4, $\dot{V}O_2max$; X_5, balance function; X_6, HDLC; X_7, TC; X_8, TG; X_9, Hb; X_{10}, total steps/day.

Table 5 shows baseline HFA and the subsequent changes in each group as calculated by the formula *(1)*. No significant differences were observed between CA and HFA at the baseline in any group. In addition, no significant changes were observed between CA and HFA in the control or SED groups at 160 weeks. However, CA and HFA differed significantly in the EX group at 160 weeks. The mean HFA was 10.7 years lower than the mean CA. The findings show that long-term exercise indeed exerts an effect on physical function and medical examination parameters. The result is a slowing or reversal in the biological aging process in elderly women.

Discussion

Very few reports have been published to date on the effects of long-term exercise training programs in elderly women. The present study evaluated such a program in which elderly women received instruction in aerobic-resistance training in a fitness class for 20 weeks. This was followed by a 3-year period (140 weeks) in which the subjects could voluntarily continue the exercise program.

Effect on physical function

The physical function parameter with the largest change in the EX group was the amount of the daily physical activity (number of steps/day). This corresponded to the exercise prescription for walking and showed a significant increase of 29% from the baseline. A total number of 9000 steps/day is equivalent to a daily energy expenditure of about 300 kcal. This amounts to more than 2000 kcal each week, which has been shown to significantly decrease mortality rate (Paffenbarger et al., 1993).

It was shown that long-term exercise had a significant effect on leg muscle power. Decreased leg power is commonly seen in middle-aged and elderly women (Ito and Yoda, 1992) and is related to the care required for these women (Cress et al., 1991). Kato et al. (2000) have noted that leg extension power of less than 2.0 W/kg is associated with difficulty in self-ambulation and usually requires the use of a walking device. Sawai (1996) reported that a leg extension power of 8 W/kg is generally necessary for elderly women to participate in daily activities. It is understood that a decrease in muscle power does not allow the recruitment of fast-twitch motor units in later life, but it is because of ADL that they become slower and movement requires less force (Aniansson et al., 1983). This emphasizes the need for appropriate resistance training of the leg muscles to prevent a decline in leg power. Our findings suggest that long-term aerobic-resistance exercise can improve leg power even in the elderly.

Long-term exercising is also effective in lowering the control needed for cardiorespiratory fitness ($\dot{V}O_2max$). A $\dot{V}O_2max$ of at least 13 mL/kg/min is necessary for independent functioning in daily activities (Shephard, 1987). However, active people require about twice this level. The mean $\dot{V}O_2max$ for all of the subjects in this study was about 20 mL/kg/min. A continued decline in this value during aging would likely have a profound effect on the ability to function independently in daily activities. This suggests the need for appropriate aerobic exercises for the improvement of the cardiorespiratory fitness in elderly women.

Improvement in physical performance parameters by long-term exercising was reflected in the improvement of ADL function. For example, shoulder joint mobility and balance are particularly important in self-care performance. Leg muscle power is likewise important in standing and walking. It was formulated that improvement contributed to a longer, healthier life for elderly women.

Balance function was evaluated by measuring motion away from the center of gravity while each subject stood with both eyes closed. In the EX group, there was no significant improvement from the baseline observed. However, the SED and control groups demonstrated marked decreases in balance. This resulted in a significant difference between the EX and control groups, suggesting an age-related decrease in balance function concerning the absence of exercise. Regular exercise thus appears useful for maintaining one's balance function.

There was no significant improvement from long-term exercise on forward body bending and grip strength. The absence of a strong association between aging or regular exercise with forward bending has also been reported (Ono, 1963). This suggests that changes in morphology or tension of the hamstrings, the antagonist muscles in forward bending, do not occur readily with exercise. Grip strength may be a highly reliable indicator of age-related changes in the elderly (Demura et al., 1996). However, training itself may have a slight effect on grip strength (Ono, 1963). Elderly people still perform many daily activities that require grip strength, making them less susceptible to the effects of disuse atrophy.

Effect on medical examination parameters

When the results of exercise therapy are examined, the conditions of pharmacotherapy of the subjects must be considered. In this study, the persons who took medicine for hyperlipidemia, hypertension, diabetes, angina pectoris and arrhythmia treatment in the baseline were excluded from the subjects. Therefore, the effects of drug involvement seem to be slight; however, all pharmacotherapies were not forbidden in this study progression, because it is not possible to completely deny that some combined effect with pharmacotherapy is also included in the results.

Many reports have described an improved lipid and glucose metabolism with exercise (Powell et al., 1987). The results were good even in the present study. The cause of the improvement seems to be because the exercise which we prescribed was aerobic-resistance training. Resistance training helps activate muscles, which is probably attributable to the increased glucose metabolism by muscle and increased insulin sensitivity. Also, aerobic exercise increases the total energy consumption and the promotion of the lipid metabolism. Another reason for the markedly beneficial effects was the long duration (160 weeks) of the exercise program.

Levels of HDLC below 40 mg/dL are generally considered suboptimal. Moreover, these levels tend to decrease in postmenopausal women (Gordon, 1977). In the elderly women with HDLC deficiency, it was indicated that long-term exercise could create improvement in the deficiency.

Hypertension in elderly people is often characterized by isolated systolic hypertension. Exercise therapy is effective for mild hypertension. Mild hypertension in the present study also showed an average lowering of 9 mmHg, which was significant in the EX group. Our findings are similar to previously reported studies of exercise therapy in patients with mild hypertension (Arakawa, 1993).

Effect of fitness program on HFA

The results of many studies support the hypothesis that a lack of regular physical activity leads to a decline in fitness level and increases the risk factors for the development of lifestyle-related disease (Tanaka and MiSook, 1996). The American Alliance for Health, Physical Education, Recreation and Dance (1980) has established exercise and fitness guidelines and recommends a fitness level, that is associated with one's health. Low fitness levels are associated with the development of lifestyle-related diseases. This has given rise to the concept of "health-related fitness." In such an approach, many studies evaluate physical fitness based on biological age, which differs from CA (Nakamura, 1990; Tanaka et al., 1990; Demura et al., 1996). However, few studies have been performed exclusively in elderly women and included longitudinal follow-up studies.

In the present study, HFA was calculated as an index of the overall fitness in the elderly women. HFA significantly decreased (representing a "younger" age) in both the EX and SED groups after completion of the fitness class. A subsequent follow-up of the changes in the EX and SED groups after completion of the fitness class revealed that HFA was profoundly influenced by whether or not the exercise program was continued. In the EX group, the improvement in the physical function parameters and medical examination resulted in a 10.7-year younger mean in HFA than CA. Our findings suggest that their health related to fitness was synthetically improved according to a continuous exercise program.

In conclusion, the evaluation of the physical function parameters after 160 weeks of exercising revealed significant improvements. The number of steps/day increased by a mean of 29% (2000 steps). Improvements in leg extension power, $\dot{V}O_2$max, rope working for self-care, side steps, sitting and standing up, and zigzag walking (by 20%, 17%, 15%, 13%, 12% and 9%, respectively) were also observed. Furthermore, the evaluation of medical examination parameters after 160 weeks of exercise revealed that hyperlipidemia and hyperglycemia improved significantly. HDLC significantly increased (by 9 mg/dL), and TC, TG, LDLC and fasting plasma glucose significantly decreased in women with values higher than the normal limits at baseline (by 26 mg/dL, 17 mg/dL, 21 mg/dL and 16 mg/dL, respectively). In women with mild hypertension, a significant decrease in mean SBP (by 9 mmHg) was observed. Our findings suggest that long-term aerobic-resistance exercise in elderly women suppresses the reduction of their health-related physical fitness.

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