Randomized Controlled Trial of Exercise Training for Older People (Sendai Silver Center Trial; SSCT): Study Design and Primary Outcome

Ichiro Tsuji [1], Akira Tamagawa [2], Ryoichi Nagatomi [2], Noriko Irie [3], Takayoshi Ohkubo [1], Masahiro Saito [3], Kazuki Fujita [2], Keiko Ogawa [2], Catherine Sauvaget [1], Yukiko Anzai [4], Atsushi Hozawa [1], Yoko Watanabe [1], Akira Sato [2], Hiroaki Ohmori [2], and Shigeru Hisamichi [1]

Physical exercise is expected to improve and maintain physical function in older people, thus promoting health and preventing or postponing the onset of disability in later life. The Sendai Silver Center Trial (SSCT) was a randomized controlled trial designed to evaluate the efficacy of exercise training among healthy free-living older people. Sixty-five eligible participants, aged from 60 to 81 years, were randomly allocated to an exercise group or a control group. The subjects in the exercise group were asked to attend training classes at the Sendai Silver Center, a municipal health and welfare facility in the center of Sendai City, at least twice a week for 25 weeks. Each training class, lasting two hours, started with a warm-up session, followed by an endurance session with a bicycle ergometer, and a resistance exercise training session using rubber films, and ended with a cool-down session. The subjects in the control group were asked to attend recreational classes at the Center twice a month. There were no drop-outs or accidents during the intervention.

Comparison of maximum oxygen consumption (VO_2max) before and after the 25-week intervention revealed a significant increase in the exercise group (2.1 ml/kg/min) but no significant change in the control group. Our result is equivalent to the participants becoming *younger* in aerobic capacity by five years after six months of exercise training.
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randomized controlled trial; exercise training; aerobic capacity; ~~the aged~~ elderly, RCT

Physical function declines with age. Aerobic capacity as measured by maximum oxygen consumption (VO_2max), for instance, is reported to decrease by approximately 0.4 ml/kg/min per year over the age of 60 years [1-4]. Studies have indicated that such decline is not inherent in natural aging, and that older people may improve or maintain aerobic capacity by exercise training and habitual physical activities [5-8]. Physical exercise is expected to promote health and prevent or postpone the onset of disability in later life. In spite of such importance, there is only limited knowledge on the beneficial effects of physical exercise for older people.

Sendai City Silver Center, a health and welfare facility for older people run by the Sendai City Health and Welfare Foundation under the auspices of the Sendai City Government, provides older people with a variety of classes such as physical exercise, cultural lectures, and recreational activities. In 1998, the Center planned to develop an exercise training program for improving aerobic capacity and physical function in older people, and to evaluate its efficacy by a randomized controlled trial. The objective of this trial was to examine the effect of 6-month exercise training for men and women aged 60 years and over on VO_2max, muscle strength, blood pressure (BP), immune measures, habitual physical activities, and quality of life.

We describe here the study design and the protocol of the Sendai Silver Center Trial (SSCT) and the marked improve-

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[1]Department of Public Health, Tohoku University School of Medicine, Miyagi, Japan.
[2]Department of Medicine & Science in Sports & Exercise, Tohoku University School of Medicine, Miyagi, Japan.
[3]Sendai City Silver Center, Sendai City Health and Welfare Foundation, Miyagi, Japan.
[4]Research Unit of Public Health Nursing, Miyagi University School of Nursing, Miyagi, Japan.
Address for correspondence : Ichiro Tsuji, MD, Department of Public Health, Tohoku University School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai, 980-8575 Japan.

ment in VO_2max by exercise training.

METHODS

Study design

The SSCT was a randomized controlled trial designed to evaluate the efficacy of exercise training among healthy free-living older people. We recruited potential participants in February 1998 and examined their eligibility at the screening session in mid-March 1998. We conducted the baseline measurement at the end of March 1998. Sixty-five subjects were stratified for age and sex and were randomly allocated into either an exercise group or a control group. We gave the exercise group 25-week exercise training from April 1998 to September 1998. At the end of September 1998, we again measured the subjects in both groups to evaluate the effect of the training. The primary outcome variable was the change in estimated VO_2max from baseline to post-intervention measurement.

Study participants

We recruited volunteers through articles in local newspapers and the City Bulletin, and posters at City Government offices, Regional Public Health Centers, and the related municipal facilities in February 1998.

Inclusion criteria were men or women aged 60 years or older, living in Sendai City. Exclusion criteria (Table 1) were related to any significant morbidity that would interfere with participation and safety in the exercise training. Since we intended to evaluate the effects of exercise training on change in blood pressure and antioxidants as secondary outcomes, we excluded the subjects who were regularly taking antihypertensive agents or vitamin supplements.

Exercise group

We gave three 2-hour classes per week. The subjects in the exercise group were asked to attend the classes at the Center at least twice a week. Each class started with a 30-min warm-up session, including static stretching of extremities and trunk muscles followed by a 10-min low-intensity stepping exercise. The main session consisted of an endurance training session using a bicycle ergometer for 20-30 min and a resistance exercise training session using rubber films for 30-40 min. Each class ended up with a cool-down session of passive muscle stretching for 20 min.

Endurance training

Subjects cycled at 50-60 rpm on a bicycle ergometer at an individually prescribed workload for 10-25 min (Table 2). The intensity of exercise was determined according to the American College of Sports Medicine (ACSM) guidelines for exercise program [9]. The intensity of exercise was calculated as % heart rate (HR) reserve from the following formula, based on the subject's predicted age-adjusted maximum HR (220 - age), and his or her seated resting HR.

%HR reserve = (target HR - resting HR) / (maximum HR - resting HR) × 100

Subjects had telemetric HR transmitters on their chest and HR monitors (Vantage NV; Polar Electro, Oy, Finland) on their wrist. HR and the workload during the endurance session were monitored to check whether exercise of the prescribed intensity was accomplished. Using this information, the trainers advised the subjects on adjusting the workload to their own target. The initial workload was set at 5-20 W. The subject increased the workload under the supervision of trainers (4-6 subjects per trainer) so that the HR gradually reached the target in the 5th minute of exercise. When the HR exceeded the target by 5% HR reserve for more than 2 min, the workload was reduced until the HR dropped to within the target. Subjects who experienced chest pain or arrhythmia were told to stop and rest.

The first week was aimed at getting the subjects familiar with bicycle ergometers. During the next 8 weeks, subjects learned how to adjust the workload by monitoring their HR. The endurance training session was periodized to avoid chronic fatigue of the participants (Table 2).

Resistance exercise training

Five exercises using rubber film manufactured for resistance exercise (Thera-Band® Resistive Exerciser, Hygenic Corp.

Table 1. Exclusion criteria for SSCT.

1. Moderate to severe motor impairment or neurological deficit
2. History of myocardial infarction, angina, or arrhythmia within six months before the study
3. Blood pressure at the screening session ≧160/100mmHg
4. Joint pain and/or arthritis limiting the full range of motion at either shoulder, elbow, hip, or knee joint
5. Mental or other conditions thought to interfere with communication at the classes
6. Other chronic disease thought to interfere with participation or effectiveness
7. History of fracture of a lower extremity or injurious falls within six months before the study
8. Use of antihypertensive agents, anti-arrhythmic agents, nitroglycerides, digitalis, or vitamin supplements
9. Presence of cardiovascular abnormality revealed by exercise testing

Akron, Ohio) were performed in a 5-stage incremental program under the supervision of an expert exercise trainer [10]. Each stage lasted 2-6 weeks, with 1-week recovery periods at the 15th, 19th, and 22nd weeks, in which the number of exercises was limited to 2 and the working strength of each exercise was reduced.

Each exercise was done 20 times, side-raise for supraspinatus and deltoid muscles, elbow flexion for biceps muscles, knee extension for quadriceps muscles, hip abduction, and hip adduction. Rubber films of various levels of strength coded by colors were cut and adjusted to appropriate length for each subject for each exercise. For each subject, rubber film of an appropriate strength was selected so that each set of 20 repetitions ended with exhaustion of the loaded muscle (20RM; repetition maximum). In the last class of each stage, the subject was asked to repeat the exercise until exhaustion. If the subject could repeat it more than 25 times, we increased the strength of the rubber film for the next stage. For the trunk curl exercise, subjects did sit-ups on the floor by raising the upper body until both shoulders were lifted more than 10 cm above the floor. The workload was adjusted to increase the number of repetitions with each stage: weeks 1-5, 10 repetitions; 6-7, 12 repetitions; 8-19, 15 repetitions; 20-25, 20 repetitions.

To minimize excessive fatigue, the subjects were asked to perform only 3 exercises for the upper body, including a trunk curl exercise, for the first 5 weeks. Table 3 shows a representative example of the resistance exercise training program of a subject.

A maximum of 17 participants exercised simultaneously under the supervision of 3 or more experienced trainers. The subjects were told to stop if they could not continue an exercise, if they could not continue the exercise properly, if the range of motion during the exercise apparently decreased, or if they complained of clinical symptoms such as palpitation, shortness of breath, or dizziness.

Safety considerations

For safety, a research nurse and a physician checked the health status and vital signs of the participants before and after each class, and attended during the classes. If a subject's BP was more than 160/95 mmHg, there was frequent arrhythmia, or pathological signs or symptoms were observed before class, the subject was advised to rest for 5 min and then BP and HR were measured again. Subjects whose BP and HR exceeded the criteria even after rest were advised not to do any training on that day.

Control group

We provided two 2-hour classes a month. The subjects were asked to attend classes at least once a month. The classes consisted of a 1-hour lecture, the topic of which was not related to physical exercise, and a 1-hour seated recreational activity such as playing games. Otherwise, they were asked to continue their usual way of life.

Ethics

All subjects gave written informed consent. The protocol of this study was approved by the Executive Board of the Sendai Health and Welfare Foundation.

Measurements (Table 4)

We measured all variables except BP and daily walking steps both before randomization and after intervention.

Eligible participants were asked to complete a 25-page questionnaire by themselves within a week. The questionnaire covered socio-demographic characteristics, medical and family

Table 2. Exercise prescription for endurance training.

Week	Phase	Target intensity of exercise (%HR reserve)	Duration of exercise (min)
1	Educational 1	<25 *	10
2-4	Educational 2	50	10
5-9	Build-up 1	50	15
10	Evaluation	**	**
11-12	Build-up 2a	50	20
13-15	Build-up 2b	60	20
16	Recovery 1	40	20
17-19	Build-up 3	60	20
20	Recovery 2	40	20
21-25	Build-up 4	60	25

* Workload was fixed for educational purposes.

** Subjects' HR response to exercise was evaluated by the same protocol as in the baseline measurement.

history, self-rated health, health-related life style such as smoking and drinking, food frequency questionnaire, and physical functional status. The last part of the questionnaire included Tokyo Metropolitan Institute of Gerontology Index of Social Competence for instrumental activities of daily living [11]. Otherwise, the questionnaire was the same as the one we had used for a baseline survey of a population-based cohort study (the Ohsaki Cohort Study) [12].

At the screening session, medical history was interviewed. Current medication was inspected and recorded. Cognitive and physical function of each applicant was also assessed. BP and HR after 2 min of sitting were measured twice using an automatic BP-measuring device (HEM 705CP, Omron Life Science, Kyoto, Japan). The average of two measurements was used.

Habitual physical activities were assessed by three different methods: a self-completed questionnaire [13], a physical activity diary in which the subjects were asked to record their activities every 15 min during waking hours, and a telemetric HR recorder during waking hours. Based on the information in

Table 3. A representative example of the resistance exercise training program for a certain subject.

Exercise	1st stage (1- 5wk)	2nd stage (6-10wk)	3rd stage (11-14wk)	4th stage (16-18wk)	5th stage (20-25wk)
Side raise	Tan (0.23)*	Tan (0.23)	Tan (0.23)	Yellow (0.33)	Yellow (0.33)
Arm curl	Tan (0.23)	Yellow (0.33)	Yellow (0.33)	Red (0.46)	Red (0.46)

Exercise	1st stage (6-10wk)	2nd stage (11-14wk)	3rd stage (16-18wk)	4th stage (20-21wk)	5th stage (23-25wk)
Knee & Hip**	Yellow (1.02)	Red (1.58)	Green (1.94)	Green (1.94)	Blue (2.83)

*: Numbers in parentheses indicate the kg weight necessary to stretch the rubber film from the initial length of 30cm to 65cm[8]

**: Knee extension, hip abduction and adduction

Table 4. Variables measured at SSCT.

Measurement	Description
Self-completed questionnaire	Socio-demographics, Medical history, Self-rated health, Health-related life style such as smoking and drinking, Food frequency questionnaire, TMIG Index of Social Competence
Health interview and physical examination	Medical history, Regular medications, Assessment of physical and cognitive function, Blood pressure
Habitual physical activities	Self-completed questionnaire, Physical activity diary, Telemetric heart rate recorder
Anthropometrics	Body weight, Body height, Circumference of arms and thighs, Skin fold thickness
Maximum oxygen Consumption (VO_2max)	Measured with a bicycle ergometer; ECG, heart rate, and blood pressure were monitored simultaneously
Isometric muscle strength	Elbow flexors and knee extensors
Timed motor performance	Functional Fitness Test
Bone mineral density	At distal end of left radius and ulna
Blood sample	Serum lipids, Immune measures, Antioxidants, Genetic polymorphism, and so forth
Skin test	Tuberculin purified protein derivative (PPD) test
Mood and fatigue	Self-completed questionnaire at each attendance to class
Self-measurement at home	Blood pressure and pedometer, everyday

physical activity diary, energy consumption of each physical activity was estimated by multiplying the duration of the activity and the rate of energy. Daily energy consumption was then calculated by summing up the energy consumption of each physical activity [14, 15]. The subjects were asked to wear their telemetric HR monitor during the week in which they completed their physical activity diary. Daily energy consumption was also calculated from the HR record. The two periods were between baseline measurement and the first day of intervention, and between the last day of intervention and the post-intervention measurement.

Body height while standing and body weight were measured with underwear only and without shoes. The circumference of both arms was measured at the midpoint between the acromion and the olecranon process. The circumference of both thighs was measured at the midpont between the great trochanter and the lateral epicondyle of the femur. The triceps and subscapular skinfold thickness were also measured. All measurements were taken only by one of us (K.O.), who is a trained expert.

An incremental submaximal exercise test was done on an electrically braked upright cycle ergometer (Aerobike 800, COMBI Corp, Tokyo, Japan) to estimate the VO_2max of the subjects. Seat height was adjusted for each subject to form a knee joint angle of 160° - 165° with the pedal crank at the lowest position. Each subject was fitted with equipment to collect respiratory gas. HR was continuously monitored with a Vantage NV HR monitor.

The subject started pedaling with an initial workload of 10 W for 2 min and was asked to keep pedaling at 60 rpm throughout the test. The resistance of the ergometer was increased every 2 min until the HR reached 85% of the participant's age-predicted maximum (220 - age). The increment was adjusted so that the total exercise time would not exceed 20 min and the subjects could go beyond 4 stages (8 min) before HR reached the target. The increment ranged from 5 to 30 W. Electrocardiogram (ECG) was recorded and BP was monitored during the last 15 s of each incremental stage by an automated patient monitoring system (EBP300, Minato Medical Science Co., Osaka, Japan).

The criteria for termination of the exercise test included development of serious arrhythmia, significant elevation or depression in the ST segment of the ECG recordings, and a rise in systolic BP above 250 mmHg. Those who met any of these criteria were excluded from the trial. Oxygen uptake and carbon dioxide output were measured every 30 s during the exercise test with an AeroMonitor 280 (Minato Medical Science Co., Osaka, Japan). VO_2max was estimated by extrapolating from a linear regression between oxygen uptake and HR measured at the end of each incremental stage to the maximum age - predicted HR (220 - age).

Isometric muscle strength of knee extensor and elbow flexor were measured on both sides. For knee extensor strength, the subjects sat on a specially designed chair with their hip joint at 90° and a knee joint at 70° . They were asked to extend their knee as hard as possible for 3 s. For elbow flexor strength, the subjects sat on a specially designed chair with their shoulder joint in a neutral position and their elbow joint held at 90° without pronation or supination. They were asked to flex the elbow as hard as possible for 3 s. Isometric strength was measured with a Hydromusculator GT-160 (OG-Giken, Okayama, Japan) for the knee extensor, and with a Musculator GT-30 (OG-Giken, Okayama, Japan) for the elbow flexor. After a practice, two measurements were taken for each joint. The larger value was used.

Timed motor performance was measured with the Functional Fitness Test, developed by the Physical Fitness Research Institute, Meiji Life Foundation of Health and Welfare [16]. This test contains four tasks: standing from the supine position, zigzag walking, hand manipulation, and self-care working. We measured the time necessary for completing each task twice, and used the smaller value. To avoid inter-rater differences in measurement, one inspector was designated for each task to measure the performance of all subjects. The time for each task was converted into a score (0-5 for each) after adjustment for age and sex as directed [16], and the summary score (full=20) was used.

Bone mineral density (g/cm²) was measured 8 mm from the distal end of the left radius and ulna by Dual Energy X-ray Absorptiometry (DEXA) method with DTX-200 (Hologic, USA).

With written informed consent, the subjects had a blood sample drawn and tested for the tuberculin purified-protein-derivative (PPD) skin reaction. The blood sample was used for measurement of complete blood count, electrolytes, cholesterol, triglyceride, antioxidants such carotenoids and vitamins A and C, endogenous nitric oxides synthase inhibitor such as asymmetrical dimethylarginine (ADMA), C-reactive protein, immune measures such as the Th1/Th2 profile of cytokine production by peripheral blood lymphocytes, and genetic analysis such as insertion or deletion polymorphisms of the gene for angiotensin-converting enzyme.

The subjects in the exercise group completed mood self-ratings on a visual analog scale [17], and a 4-rank score test for 3 subcategories of fatigue: systemic fatigue, psychological fatigue, and local symptoms related to fatigue [18].

BP and daily walking steps of all subjects were measured throughout the intervention period. The subjects were given an automatic BP-measuring device (HEM 705CP), and were instructed to measure BP while seated, within 1 h of awaking every day. The subjects were also given a pedometer (Select II, Suzuken, Nagoya, Japan), and were instructed to attach it at their waist during waking hours. The subjects were asked to record the measurements every day and to report them every other week to the Center.

Group allocation and masking

After all baseline measurements were completed, epidemiologists (Y.N. & K.O.), who were masked from the measurement results, allocated subjects to groups by using a random numbers table. The participants were informed of their allocation status by telephone. Group allocation was not masked to the inspectors at the post-intervention measurement, but was masked to the investigators who were in charge of measurement of blood samples and statistical analysis.

Outcome variables

Primary outcome variable of this trial was an improvement in VO_2max by physical exercise. We expected an increase in VO_2max by 15% in the exercise group and a drop-out rate less than 5%. Based on this expectation, a sample size of 30 pairs would allow a significance level of 0.05 and a power of 0.80.

Secondary outcomes included the effects of exercise training on changes in muscle strength, BP measured at home, habitual physical exercise, mood, bone mineral density, serum lipid levels, serum ADMA level, and immune function. We also intended to explore the relationship between the training effect and the baseline characteristics such as antioxidant levels, ADMA levels, and gene polymorphism.

Statistical analysis

Baseline characteristics were compared between the exercise and control groups by using χ^2-test and Student's t-test as appropriate. Analysis of variance with repeated measurement was used to compare VO_2max before and after training. The net gain in VO_2max was measured as (VO_2max at post-intervention - VO_2max at baseline) in the exercise group - (VO_2max at post-intervention - VO_2max at baseline) in the control group. All statistical analyses were made with SAS [19], and $p<0.05$ was considered as statistically significant.

RESULTS

Recruitment and participant flow (Figure 1)

In response to our recruitment, 322 men and women called the Center. According to a pre-designed scheme, staff explained the objectives, schedule, contents, and intensity of this trial, and the inclusion and exclusion criteria. At this step, 113 subjects declined to apply, mainly because the intensity and frequency of the trial were beyond their expectations. The remaining 209 possible participants attended the screening session, and 121 were excluded. The numbers of subjects excluded for each criterion are shown in Figure 1. Of 88 eligible subjects, 78 attended the baseline measurement. Twelve were excluded because of varying medical and physical conditions: abnormal exercise ECG (N=3), angina during exercise (N=1), systolic BP at exercise more than 250 mmHg (N=6), and inability to ride a bicycle ergometer (N=2). Another was excluded because of severe anemia. Out of 65 eligible participants, 32 were randomly allocated to the exercise group and 33 subjects to the control group.

Throughout the 25 weeks of intervention, there was no drop-out from either group. The mean attendance rate for each class was 78.2% in the exercise group and 84.5% in the control group. In the exercise group, 28 subjects (82%) attended at least twice a week throughout the course. Among 33 subjects in the control group, 31 subjects (94%) attended at least once a month through the course. No one was injured in a fall or experienced a cardiovascular event. Two subjects in the exercise group reported that they started taking an antihypertensive agent after the training had started.

At the end of September 1998, all but one subject in the exercise group and all subjects in the control group participated in the post-intervention measurement. The subject who missed the measurement did so because she had to look after her daughter who was acutely hospitalized a few days before the measurement.

Baseline characteristics

The subjects aged from 60 to 81 years, and 15 out of 65 subjects aged 70 years or more. Table 5 shows the characteristics of the participants at the baseline measurement. No variable was significantly different between the exercise and control groups. All participants were independent in instrumental activities of daily living.

Change in VO_2max

Table 6 shows the means (SD) of VO_2max for each group before and after the intervention. The subject who missed the post-intervention measurement is excluded. VO_2max in the exercise group increased significantly by 15.5%, from 23.7 to 26.8 ml/kg/min. It also increased in the control group, although not significantly. The net gain in VO_2max by exercise training was 2.1 ml/kg/min ($p = 0.040$), which corresponds to an increase of 10.3% ($p = 0.029$). After excluding two subjects in the exercise group who started taking an antihypertensive agent, the result was not changed (data not shown).

Figure 2 shows the degree of improvement in VO_2max among the subjects in the exercise group from the baseline value. The degree of improvement was calculated as (VO_2max at post-intervention - VO_2max at baseline) / VO_2max at baseline. There was a significant negative correlation ($r = -0.488$; $p < 0.001$) between these two variables, suggesting that the effect of physical exercise in this trial was greater among the subjects with a lower baseline VO_2max.

DISCUSSION

To our knowledge, this is the first randomized controlled trial in Japan to evaluate the effect of exercise training on

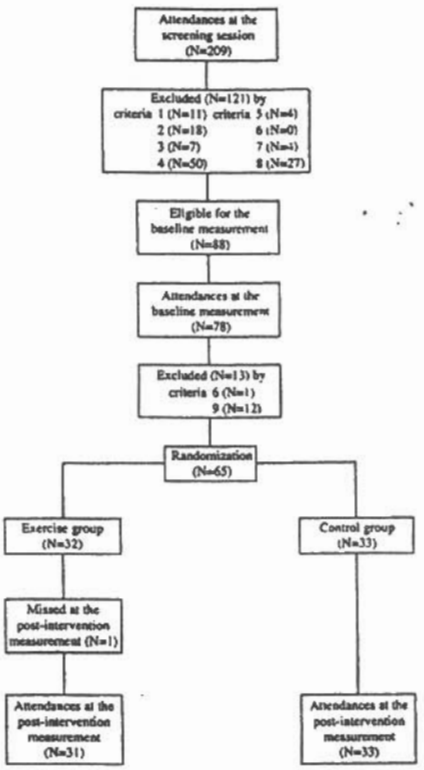

Figure 1. Flow chart showing numbers and timing of randomization to exercise or control groups, interventions, and outcome measures.

Table 5. Characteristics of subjects in exercise and control groups at entry to trial.

Characteristics	Exercise group (N=32)	Control group (N=33)	P-value
Age (years)	67.3 (4.8)	66.9 (3.0)	0.71
Female sex (%)	53.1	54.6	0.91
Systolic BP (mmHg)	140.2 (12.4)	138.6 (12.5)	0.60
Diastolic BP (mmHg)	77.2 (9.5)	78.8 (9.6)	0.49
Body mass index (kg/m^2)	23.2 (2.8)	23.1 (2.9)	0.89
VO2max (ml/kg/min)	23.6 (5.6)	24.7 (4.9)	0.38
Elbow flexor (kg): Rt	14.5 (4.8)	14.1 (4.2)	0.67
Elbow flexor (kg): Lt	14.1 (4.5)	14.0 (4.1)	0.84
Knee extensor (kg): Rt	43.5 (18.4)	43.7 (13.9)	0.95
Knee extensor (kg): Lt	43.4 (16.8)	43.5 (14.0)	0.99
Functional Fitness Score	15.2 (2.2)	14.9 (2.3)	0.62
Bone mineral density (g/cm^2)	0.427 (0.099)	0.426 (0.088)	0.94
Daily walking steps	9205.9 (2424.8)	8974.2 (2109.5)	0.68

Values were expressed as means (SD) except female sex. P-value with χ^2-test for female sex, otherwise with Student's t-test.

VO_2max in older people. The participants tolerated with the exercise training well, and the training was effective in enhancing VO_2max by 2.1 ml/kg/min. The degree of the gain in VO_2max by our trial was consistent with the past trials outside Japan [5-7]. Because the purpose of this article is to describe the design of the SSCT, we limit the presentation of outcomes to

Table 6. Comparison of mean (SE) of VO_2max (ml/kg/min) at SSCT.

Group	N	Pre (ml/kg/min)	Post (ml/kg/min)	(Post-Pre) change		Net change***(95%CI)†††	
				ml/kg/min	%	ml/kg/min	%
Exercise	31*	23.7 (1.0)	26.8 (1.0)†	3.1 (0.7)	15.5 (3.4)	2.1** (0.1-4.1)	10.3†† (1.2-19.4
Control	33	24.7 (0.9)	25.7 (0.9)	1.0 (0.7)	5.2 (3.1)		

* The subject who missed the post-intervention measurement was excluded.
† P<0.001 vs pre-intervention
** P=0.040
†† P=0.029
*** The difference between the change in the exercise group and the change in the control group.
††† CI: confidence interval

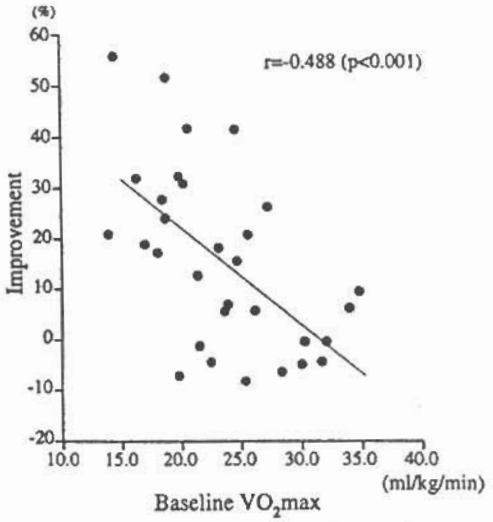

Figure 2. The degree of improvement in VO_2max among the subjects in the exercise group according to the baseline VO_2max.

the change in VO_2max only. We will report the effects on the secondary outcome in subsequent publications.

Characteristics of the participants and external validity

We selected the participants according to exclusion criteria. The participants were asymptomatic at the submaximal exercise tests, and tolerated with the 25-week exercise training well. Thus, they were apparently active and healthy, and their health and functional status would be higher than that of the general population at this age. Comparison of the baseline characteristics of our subjects and the normative data for this age-group in Japan is important in considering the degree of selection bias and the external validity of our findings.

According to National Nutritional Survey [20] in Japan in 1996, the mean (SD) BP among those aged 60-69 years was 145.7 (19.0) / 85.5 (11.5) mmHg for men and 143.4 (20.1 83.7 (11.1) mmHg for women. The mean values in our parti pants were lower than this. The mean (SD) body mass ind was consistent with the national average, which is 23.0 (2.9) men and 23.6 (3.5) in women, aged 60-69 years [20]. The me score of the Functional Fitness Test was higher than the me values for age and sex, that is 12 [10]. The mean (SD) daily st count of the participants was greater than the national averag which is 6920 (3781) for 60-69 years [20]. Mean VO_2max w comparable with or slightly lower than that in participants exercise testing at the Tokyo Metropolitan Health Promoti Center (27.3 for men and 23.4 ml/kg/min for women 60- years) [4]. Thus, our participants were more active and healt than the general population at this age, but not as much as el athletes. Our trial proved the efficacy of exercise training f

active and healthy older subjects. There is no evidence for generalizability of the present findings to other types of older people. A beneficial effect of training for sedentary, less fit, or frail older people must be tested by another randomized trial.

Implication of gain by exercise training

Our findings indicate that 25-week exercise training increased VO_2max by 2.1 ml/kg/min of the participants at the exercise group. VO_2max is reported to decrease by approximately 0.4 ml/kg/min per year among those aged more than 60 years [1-9]. Our result is equivalent to the participants becoming *younger* in aerobic capacity by five years after six months of exercise training.

Although the participants' aerobic capacity may now start to decline, the gain achieved by this trial may significantly extend their span of active and healthy life. Their VO_2max, muscle strength, and habitual physical activity will be followed up, and the long-term effect of the exercise training in later life will be investigated.

Perspectives for health policy and future research

Disability in later life not only interferes with the quality of life of older people and their caregivers, but also imposes a large burden on society. According to community-based observation in rural Japan, the medical cost for those with limitation in activities of daily living was about three times as much as for those without functional limitations [21]. The economic impact of preventing disability and extending the span of healthy life must be substantial. There is an urgent need to provide cost-effective intervention programs to prevent or postpone the onset of disability in later life. We expect exercise training to be one such program.

Our trial was aimed at proving the efficacy of exercise training for older people. Though it proved to be effective, the program required a large amount of staff, equipment, and cost. An exercise training program based on specialized facilities might not meet the requirements of a public health program which should be simple, easy, affordable, and effective. Development of programs to enhance habitual physical activities among older people at home or community at a feasible level of professional involvement and cost is now required. The long-term effect of disability prevention by exercise training for the older people in the community and its cost-effectiveness must further be appraised by a large-scale RCT [22].

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APPENDIX

List of SSCT Investigators

Principal Investigator: Ichiro Tsuji [1]; Advisory Committee: Shigeru Hisamichi [1], Hiroaki Ohmori [2], Hideo Hashimoto [3], Noboru Kokubo [3], Shin-ichi Shoji [3], Kei Kudo [4]; Project Office: Tomohiko Konno [3], Noriko Irie [3], Masahiro Saito [3]; Randomized Allocation Committee: Yoshikazu Nishino [1], Keiko Ogawa [1]; Eligibility Committee: Catherine Sauvaget [1], Seiki Kanemura [1], Aya Kuwahara [1], Chikako Nakagawa-Okamura [1], Peng Hua Qiang [1]; Measurement Committee: Akira Tamagawa [2], Takayoshi Ohkubo [1], Akira Sato [2], Keiko Ogawa [2], Tasuku Sato [5], Masafumi Ohsako [6], Tetsuro Suzuki [7], Yoshitaka Tsubono [1], Yoko Watanabe [1], Osamu Takeda [1], Yuko Yoshida [1], Zhang Xiu Ming [2], Osamu Kanemi [2], Koya Sato [2], Yutaka Imai [7], Hirotoshi Sasaki [2]; Training Committee: Ryoichi Nagatomi [2], Kazuki Fujita [2], Mie Izumi [3], Eiko Kitame [3], Reiko Konishi [3], Midori Neda [3], Megumi Watanabe [3]; Safety and Monitoring Committee: Atsushi Hozawa [1], Yukiko Anzai [4], Setsuko Goto [3], Junko Tanaka [3]. Laboratory Centers: Jituo Higaki [8], Tomohiro Katsuya [8], Kazuhiro Ishikawa [7] (genetic analysis), Yoshinori Itoh [9] (antioxidants), Mieko Kawamura [10] (Vitamin C), Mitsuharu Okutsu [2] (immunology).

[1] Department of Public Health, Tohoku University School of Medicine

[2] Department of Medicine & Science in Sports & Exercise, Tohoku University School of Medicine

[3] Sendai City Silver Center, Sendai City Health and Welfare Foundation, Miyagi, Japan

[4] Research Unit of Public Health Nursing, Miyagi University School of Nursing

[5] Department of Sports Science, Faculty of Physical Education, Sendai College

[6] Department of Sports and Health Science, Course of Liberal Arts, Toyo University

[7] Second Department of Internal medicine, Tohoku University Graduate School of Medicine

[8] Department of Geriatric Medicine, Osaka University Medical School

[9] Department of Public Health, Fujita Health University School of Health Sciences

[10] Department of Nutrition, Kochi Prefectural Women's College

REFERENCES

1. Buskirk ER, Hodgson JL. Age and aerobic power; the rate of change in men and women. Fed Proc, 1987; 46: 1824-1829.
2. Ichikawa T. Aerobic power of Japanese in relation to age and sex. Hung Rev Sports Med, 1980; 21: 243-253.
3. Miyawaki M. Nihon-jin no Tairyoku Heikin-chi (Standard value of Physical Fitness in Japanese). pp. 236-242, Fumaido, Tokyo (in Japanese), 1989.
4. Tokyo Metropolitan Foundation for Health Promotion. Korekara no Kenkou Zukuri (Health Promotion for Future). Tokyo Metropolitan Health Promotion Center, Tokyo (in Japanese), 1998.
5. Hagberg JM. Effect of training on the decline of VO_2max with aging. Fed Proc, 1987; 46: 1830-1833.
6. Seals DR, Hagberg JM, Hurley BF, et al. Endurance training in older men and women. I. Cardiovascular responses to exercise. J Appl Physiol: Respirat Environ Exercise Physiol, 1984; 57: 1024-1029.
7. Thomas SG. Determinants of the training response in elderly men. Med Sci Sports Exer, 1985; 17: 667-672.
8. Lai JS, Lan C, Wong MK, et al. Two-year trends in cardiorespiratory function among older Tai Chi Chuan practitioners and sedentary subjects. J Am Geriatr Soc, 1995; 43: 1222-1227.
9. American College of Sports Medicine. Guidelines for Exercise Testing and Prescription, 4th Ed. Lea and Febiger, Philadelphia, 1991.
10. The Hygenic Coorporation. Instruction Manual for Thera-Band Resistive Exercise. 3 rd Edition. The Hygenic Coorporation, Akron, 1996.
11. Koyano W, Shibata H, Nakazato K, et al. Measurement of competence: reliability and validity of the TMIG index of competence. Arch Gerontol Geriatr, 1991; 13: 103-116.
12. Tsuji I, Nishino Y, Ohkubo T, et al. A prospective coh study on National Health Insurance beneficiaries Ohsaki, Miyagi Prefecture, Japan: Study design, profil of the subjects and medical cost during the first year Epidemiol, 1998; 8: 258-263.
13. Naito Y. Relationship between physical activity a health examination variables in male workers. Jpr Public Health, 1994; 41: 706-719. (in Japanese)
14. Bouchard C, Tremblay A, Leblanc C, et al. A method assess energy expenditure in children and adults. An Clin Nutr, 1983;37:461-467
15. Ainsworth BE, Haskell WL, Leon AS, et Compendium of physical activities: Classification energy costs of human physical activities. Med S Sports Exerc, 1993; 25:71-80
16. Oida Y, Arao T, Nishijima Y, Nagamatsu T, Maeda Measurement method of a Functional Fitness Test for t elderly, and its age- and sex-specific normative valu Bull Phys Fitness Res Inst, 1994; 86: 31-36. (in Japane
17. Tyrer P. The Role of Bodily Feelings in Anxiety. Oxf University.Press, Oxford, 1976.
18. Aoyama H. Fatigue during working and its soluti Rinsho Sports Igaku, 1986; 3: 504-511. (in Japanese)
19. SAS Institute. SAS/STAT User's Guide, Release 6. Edition. SAS Institute Inc., Cary, 1988.
20. Ministry of Health and Welfare, Japan. Kokumin Eiy no Genjou 1996 (Report of National Nutrition Surve Daiichi Shuppan Co, Tokyo, 1998 (in Japanese)
21. Tsuji I, Kuwahara A, Nishino Y, et al. Medical cost disability: a prospective observation of National Hea Insurance beneficiaries in Japan. J Am Geriatr S 1999; 47: 470-476.
22. Leville SG, Guralnik JM, Ferrucci L, Langlois J Aging successfully until death in old age: Opportuni for increasing active life expectancy. Am J Epidem 1999; 149: 654-664.