

# Long-term Stretching Program in Older Active Adults Increases Muscle Strength

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## Abstract

The purpose of this study was to evaluate the long-term and repeated bout effects of static stretching (SS) program in older active adults, and to clarify the effects of flexibility on muscle strength of knee and trunk. The subjects were healthy active adults (aged 67–80 years). The intervention group (n = 7) performed the SS program for 1 year and an additional period of 2 years. The SS program was configured to target the body's major muscle groups, and the exercises were performed five times a week. The peak torques in extension and flexion of knee and trunk (isokinetic contraction 60°/sec) were obtained from isokinetic dynamometer, and sit and reach test was assessed yearly. As a result, flexibility was increased by 31% during the first SS intervention (period of 1 year), and muscle strength were also increased by about 10% to 17%. Additionally, a higher effect was obtained by the second SS intervention (period of 2 years). We found a significant correlation between the magnitude of changes in flexibility and muscle strength. Therefore, the repetition of an SS program is important for improving or maintaining flexibility and muscle strength in older active adults.

**Keywords:** Sit and Reach Test; Static Stretching Program; Flexibility; Long-term Repeated bout effect

## Abbreviations

Static stretching (SS); Range of motion (ROM)

## Introduction

Structural and functional deterioration and a decrease in flexibility occur in most physiological systems with advancing age. Poor flexibility in musculoskeletal is associated with falls<sup>[1,2]</sup>, disc herniation<sup>[3]</sup>, and low back pain<sup>[3,4]</sup>; however, it can be improved at any age.<sup>[5-8]</sup> Flexibility programs with aerobic exercise and resistance training reduce these risks.<sup>[1,2,5]</sup> According to the American College of Sports Medicine (ACSM)<sup>[5]</sup>, the purpose of a flexibility program is to develop range of motion (ROM) in the muscle-tendon groups in accordance with individualized goals, and static stretching (SS) can improve flexibility. SS involves slowly stretching a muscle and/or tendon group and holding the position (e.g., 10–30 sec). Older adults may experience greater transient improvements in flexibility with longer durations

(30–60 sec) of SS.<sup>[9-11]</sup> It is important to attain 60 sec of total stretching time per flexibility exercise by adjusting the duration and repetitions.<sup>[4-6]</sup> Performing a flexibility program 2–3 times a week is effective for increasing flexibility<sup>[7,12]</sup> but greater gains in flexibility are accrued with a daily flexibility program.<sup>[9,13,14]</sup> Furthermore, flexibility can be improved after 3–12 weeks of a regular SS program at a frequency of at least 2–3 times a week.<sup>[7,15-17]</sup> Our research group has also demonstrated that long-term SS program improve the total peripheral vascular function.<sup>[18]</sup> Thus, exercise programs that include a flexibility program are often recommended for older adults. However, little is known about the long-term effects of focusing on flexibility in older adults who participate in regular exercise. To our knowledge, the longest follow-up study is 5 years<sup>[19]</sup>, but the long-term repeated bout effects are still unclear. The number of older adults is growing; thus, helping this population maintain flexibility is important.

Flexibility is characterized by the maximum ROM in a joint or series of joints.<sup>[20]</sup> One method is to measure the angle between the segments adjacent to one joint (e.g., measurement of ROM), and another method is to conduct a traditional composite inspection such as a sit and reach test. The angular test is complex, requiring sophisticated instruments, qualified technicians, and time constraints, and it is limited in several settings, including clinical, large-scale and long-term studies.<sup>[21]</sup> Alternatively, the sit and reach test is a highly useful and simple method that is often used in long-term studies, and this test provides the sum of all joint angles as a composite test.<sup>[21,22]</sup>

It has recently been reported that acute or short-term SS temporarily decreases muscle strength.<sup>[23-25]</sup> This phenomenon is known as “stretching-induced force deficit”, and some reports have also described decreases in isometric muscle strength<sup>[23,24]</sup>, muscle endurance<sup>[25]</sup>, sprinting speed<sup>[26]</sup> and vertical jump height.<sup>[27]</sup> On the other hand, the medium-term study in which SS program was continuously conducted in healthy individuals for 6 to 10 weeks shows, however, that isometric strength does not change<sup>[13]</sup> and one repetition maximum [1RM]<sup>[15]</sup> increases. This response was confirmed not only in healthy individuals but also in elderly individuals. Batista et al.<sup>[28]</sup> reported that

an SS program was continuously conducted in elderly female individuals for 4 weeks (SS 1 min, 7 times per day, twice a week), and as a result, isometric strength of the knee joint at 60°/sec significantly increased (8% to 12%). As described above, the medium-term SS program may increase not only flexibility but also muscle strength. To our knowledge, however, there is no report of a study investigating changes in muscle strength using a long-term SS program.

We hypothesized that muscle strength is affected by increased flexibility. Therefore, in our longitudinal study, we evaluated the long-term and repeated bout effects of an SS program in older active adults and attempted to clarify the effects of muscle strength in flexibility.

**Methods**

**Participants and study design**

This study was approved by the local ethics committee and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants. Although it is understood that flexibility in older adults can be improved [4-6], it is not clear whether the effect is due to the SS program, because aerobic exercise and strength training are also being performed simultaneously in many cases. [29] To ensure that the intervention was truly an effect of SS, fourteen healthy active adults (aged 67-80 years, mean 74.2 ± 6.1 years) without cardiovascular and orthopedic diseases who participated in a regular health class at least 3 years ago were recruited for

this study. The 1h health class was performed twice a week and included aerobic and strength training components that followed the ACSM recommendations [4, 5] on comprehensive exercise programs for older adults. The subjects were randomly divided into two groups: intervention group and control group (Figure 1). To avoid contact between the groups, participants in the intervention group attended a health class on a different day of the week from the control group. Thus, the intervention group participated in a health class and SS program, while the control group participated only in a health class. The health class in both groups was the same program performed by two exercise instructors, and stretch exercises (i.e warm-up and cool-down) were allowed. At the start of the study, the intervention group included 7 participants (2 men, 5 women; aged 65-80 years, mean 73.6 ± 6.9 years), and the control group included 7 participants (2 men, 5 women; aged 65-82 years, mean 74.9 ± 6.1 years). To confirm the repeated bout effects, the SS program in the intervention group was performed for 1 year during the study's second year and for 2 years during the fourth and fifth years of the study. Each group performed the following measurements yearly (Figure 1): sit and reach test as an indicator of flexibility, flexion and extension of knee and trunk as an indicator of muscle strength, height, body weight, body fat percentage, lean body mass, systolic blood pressure (SBP), diastolic blood pressure (DBP), and volume per time oxygen maximum (VO<sub>2</sub>max).

**Static stretching program**

Referring to previous reports [4, 5, 18], the SS program targeted

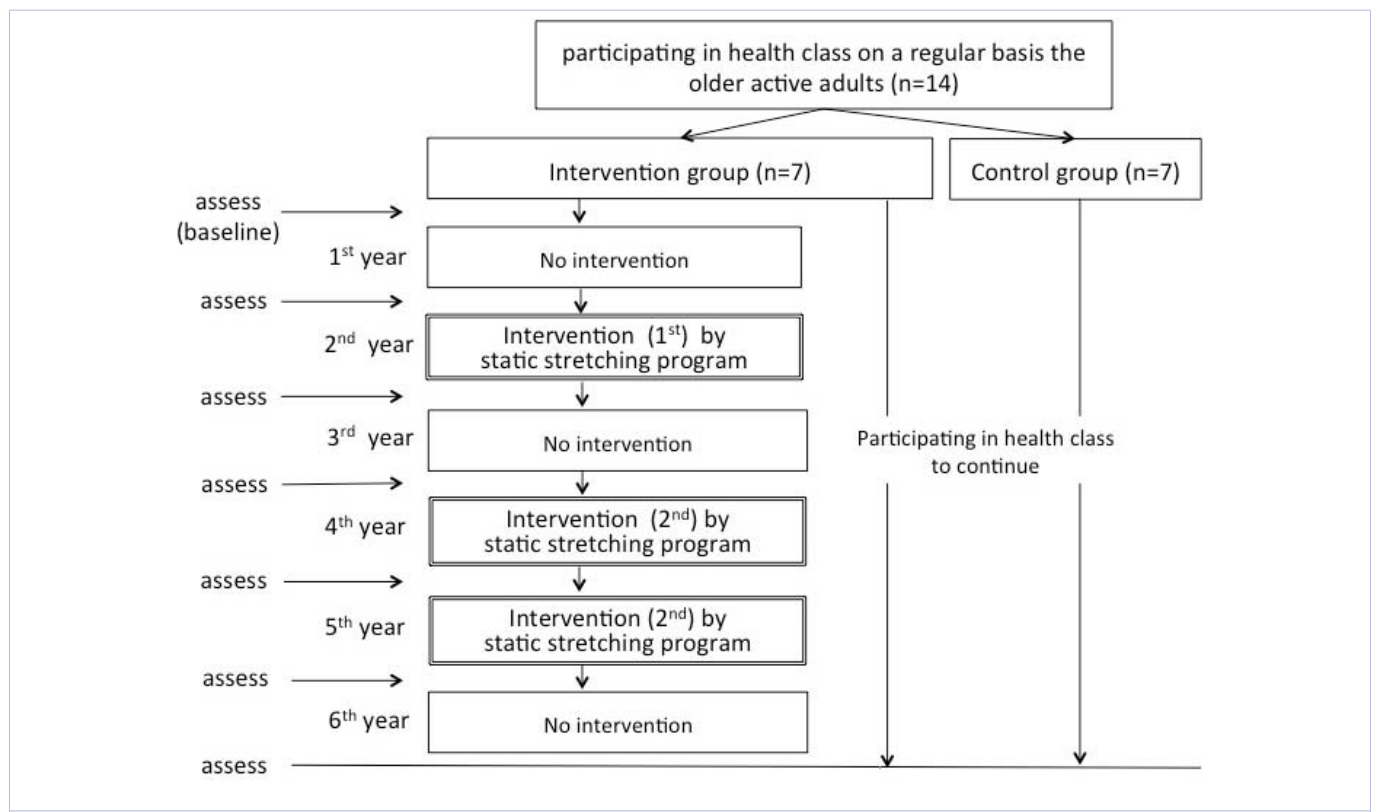


Figure 1: Experiment protocol.

the body's major muscle groups and was limited to 10 minutes within the time required for all programs. For example, one stretch technique was allotted 1 min and was composed of a total of 10 technique patterns [5, 6, 16] (Figure 2). The SS was performed by all subjects in intervention group, and the subjects performed to feel subjectively a stretching degree of "appropriate stretching" or "slightly excessive stretching".<sup>[30]</sup> The intervention group participated in the collective leadership of the SS program by an exercise physiologist before joining the health class twice a week. Furthermore, the subjects performed SS three times a week (once per day) and a similar program as a home exercise. Therefore, subjects in the intervention group performed the SS program a total of five times per week (once for 10 min × once per day × five time a week).

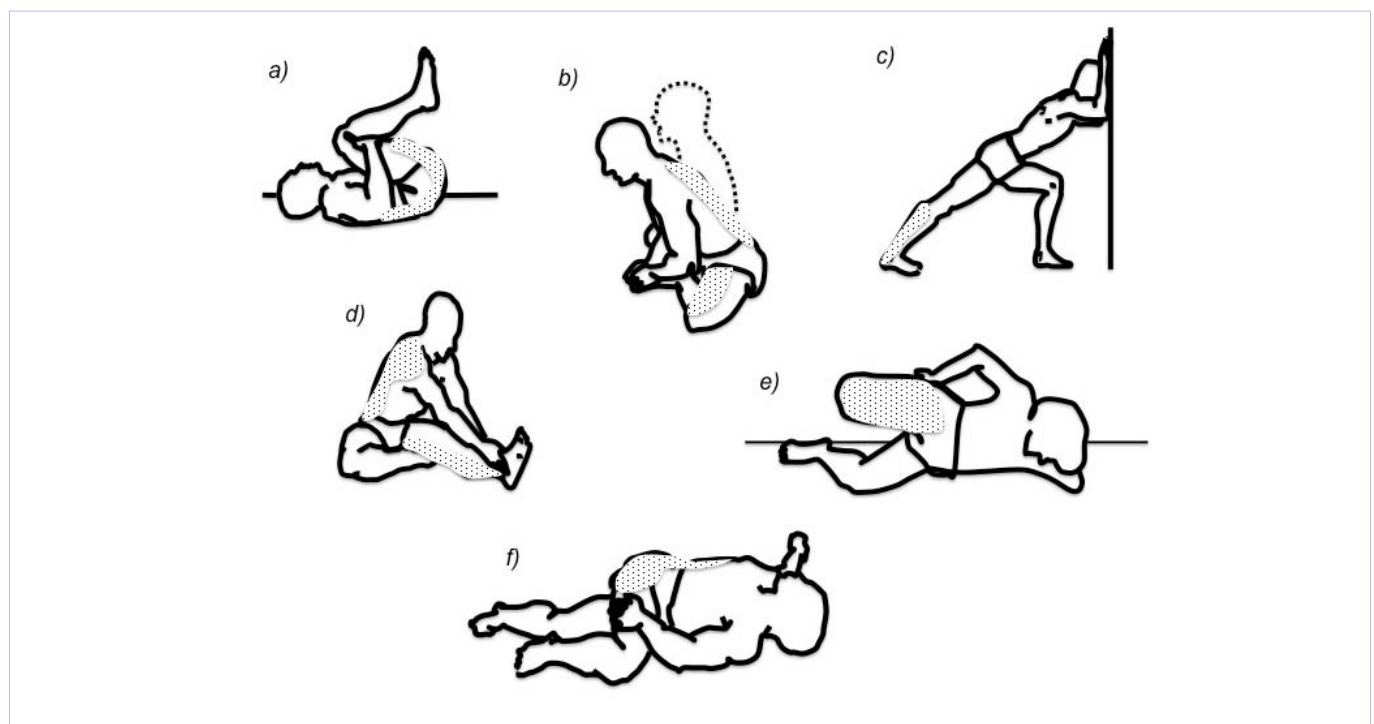
**Measurement of each parameter**

**Morphology and flexibility:** We measured height, body weight, body fat percentage, and lean body mass as a morphometric model. Height was measured using a measuring machine (DP-7100PW; Yamamoto Scale, Hyogo, Japan), and body weight, percent body fat, and lean body mass were measured by the impedance method using a digital analyzer machine (TBF-102; Tanita Corp., Tokyo, Japan). Flexibility was determined by the sit and reach test using a measurement apparatus (TKK-511; Takei Scientific Instruments Co., Ltd., Niigata, Japan), as described by the ACSM protocol.<sup>[31]</sup> Specifically, subjects sat on the floor without bending their knees, and then they flexed their trunk slowly; the distance between the tip of the finger and the sole of the foot at that time was measured. Subjects were instructed not to hold their breath in consideration of the Valsalva effect. The

measurement value was positive when the tip of the subjects' finger exceeded the sole of their foot, but it was negative in the reverse case. Three measurements were taken within 3 min intervals between the measurements. The average of the two measurements, except for the first measurement, was used for further analysis.

**Measurement of muscle strength:** The subjects started measurement of muscle strength after warm-up (warmed up on a bicycle for 5 min at 20 km/hr<sup>[28]</sup>). The cybex system isokinetic dynamometer (Cybex NORM 770, Henley Healthcare, USA) was used for measurement of flexion and extension of knee and trunk muscle strength. Attention was paid to a possible Valsalva effect, testing was performed at a maximum of five repetitions for knee and trunk extension/flexion at isokinetic speeds of 60 degrees/sec. Isokinetic test results were analyzed with the cybex system software, determined the peak torque value of each measurement. In addition, knee strength was taken as the representative value of the average value of the left and right. The muscle strength assessment was supervised by the one people examiner.

**Measurement of cardiopulmonary system function tests:** The SBP and DBP were measured by using the digital automatic blood pressure meter (BP-203RV2; Nihon-Colin Co., Ltd., Tokyo, Japan). The value of SBP and DBP were adopted as the representative value of the average value of 3 times. The VO<sub>2</sub>max was measured on a MAT-2500 treadmill (Fukuda Denshi, Tokyo, Japan) using the Bruce protocol. Throughout the exercise stress test, the 12-lead electrocardiogram was continuously monitored (ML-5000; Fukuda Denshi, Tokyo, Japan). The VO<sub>2</sub> was measured throughout the exercise period using an AE-300S Aero monitor



**Figure 2: Static stretching program.** Each SS performed in 1 minute, and it is configured a total 10 minutes. Dot pattern shows the stretch site. In addition, c to f is performed the left and right.

(Minato Ikagaku Co., Tokyo, Japan) and was calculated using a personal computer (Pentium Processor, Windows XP; Epson, Nagano, Japan). The endpoint of the exercise testing was determined according to the American Heart Association's criteria.<sup>[32]</sup>

**Reproducibility of the flexibility and muscle strength measurements:** We confirmed the reproducibility of the flexibility and muscle strength (flexion and extension of knee and trunk) measurements against the three subjects at different occasions. As a result of performing the same procedures, the coefficient of variation (CV) of the three measured values were  $3.8 \pm 1.4\%$  with an intra-class correlation coefficient type 1,3 [ICC(1,3)] of 0.98 ( $p < 0.001$ ) in flexibility. Likewise, the CV values were  $2.4 \pm 1.1\%$  in knee flexion strength,  $1.7 \pm 0.8\%$  in knee extension strength,  $2.6 \pm 1.1\%$  in trunk flexion strength, and  $3.5 \pm 1.9\%$  in trunk extension strength with ICC (1,3) of 0.85 in knee flexion strength, 0.85 in knee extension strength, 0.98 in trunk flexion strength, and 0.95 in trunk extension strength, respectively ( $P < 0.001$ ).

**Statistical Analysis**

Two-way repeated measures analysis of variance was conducted for all numerical data, and Bonferroni's test was used for the post hoc analyses. Pearson's product-moment correlation coefficients were used for the correlation analyses among all the parameters. SPSS, version 12.0 for Windows (SPSS, Chicago,

IL, USA) was used for statistical analyses, and the statistically significant level was set at less than 5%.

**Results**

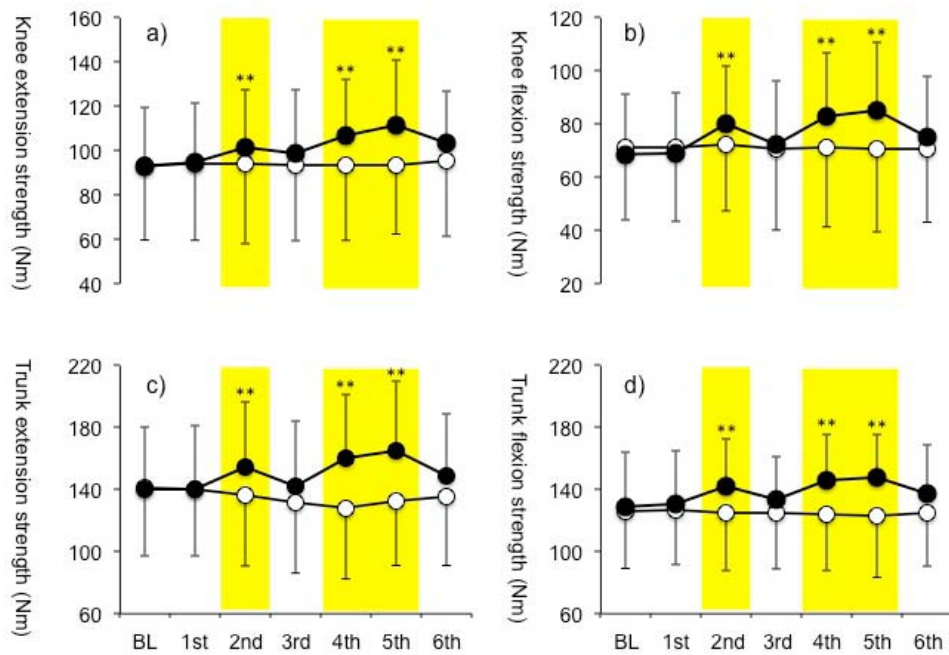
The changes in morphological, flexibility, and cardiopulmonary system compared with the baseline are shown in Table 1. There were no significant changes in the control group during the study period. However, the intervention group, during the periods of performing the SS program, showed significant changes in flexibility and lean body mass (Table 1). A significant relationship was found between the intervention and control group for these parameters ( $p < 0.01$ ). The changes in muscle strength (flexion and extension of knee and trunk) are shown in (Figure 3). For flexibility and muscle strength (flexion and extension of knee and trunk), there were significant differences between the intervention effect of the first (2<sup>nd</sup> year) and second time (4<sup>th</sup> and 5<sup>th</sup> year). Additionally, there was a significant difference between the 4<sup>th</sup> and 5<sup>th</sup> year ( $p < 0.05$ ), respectively. The flexibility was significantly different between the beginning and the end of each SS program (baseline, 3<sup>rd</sup> and 6<sup>th</sup> year) ( $p < 0.05$ ), but muscle strength were not maintained.

Figures 4 and 5 show the correlation between the magnitude of change in flexibility and muscle strength on intervention group. A significant relationship was found between the changes in flexibility and the changes in muscle strength (flexion and extension of knee and trunk). However, correlation coefficients

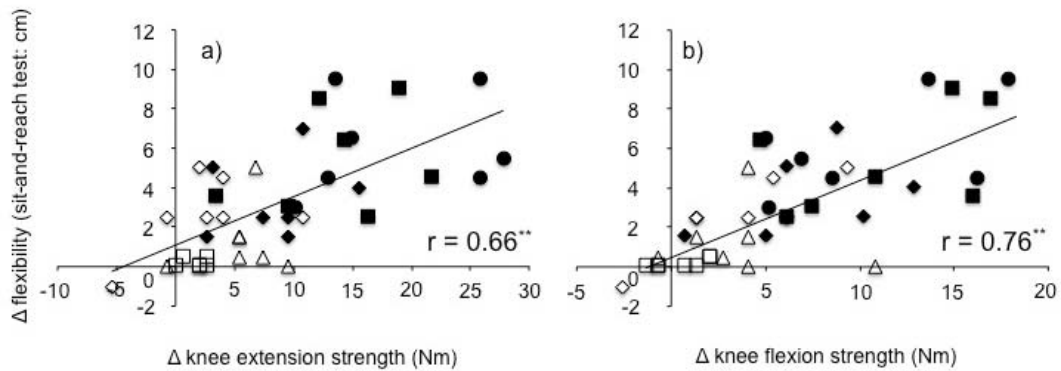
**Table 1:** Changes in morphological, flexibility, and cardiopulmonary system function tests against baseline. \*: significantly ( $p < 0.05$ ) and \*\*: significantly ( $p < 0.01$ ) different from baseline.

		baseline	1st year	2nd year (intervention)	3rd year	4th year (intervention)	5th year (intervention)	6th year
height (cm)	intervention group	157.3 ± 8.8	157.3 ± 8.8	157.1 ± 8.7*	157.1 ± 8.7*	157.1 ± 9.0*	157.0 ± 8.7*	157.0 ± 8.9*
	control group	155.9 ± 10.6	155.8 ± 10.6	155.5 ± 10.5	155.5 ± 10.5	155.5 ± 10.4	155.4 ± 10.4	155.4 ± 10.6
weight (kg)	intervention group	56.1 ± 7.4	56.3 ± 7.6	56.0 ± 8.9	55.7 ± 7.9	55.3 ± 8.8	55.0 ± 8.3	55.6 ± 7.8
	control group	54.8 ± 9.9	54.5 ± 9.9	54.7 ± 9.2	54.1 ± 9.9	54.1 ± 9.3	54.7 ± 9.3	54.6 ± 9.5
body fat (%)	intervention group	21.7 ± 4.7	21.8 ± 4.9	21.0 ± 5.2	21.1 ± 5.1	20.5 ± 5.0*	21.0 ± 4.8	22.2 ± 5.9
	control group	23.3 ± 7.6	23.4 ± 7.6	23.3 ± 7.6	23.8 ± 7.7	23.1 ± 7.6	23.0 ± 7.5	23.1 ± 7.9
lean body mass (kg)	intervention group	43.9 ± 8.3	44.1 ± 8.2	44.8 ± 7.7*	43.9 ± 8.6	44.7 ± 8.9*	44.5 ± 8.8*	43.6 ± 8.2
	control group	43.3 ± 10.0	43.3 ± 9.8	42.9 ± 9.4	42.5 ± 9.8	42.1 ± 9.8	41.8 ± 10.2	42.0 ± 10.0
sit and reach test (cm)	intervention group	10.7 ± 6.1	10.9 ± 6.1	14.1 ± 6.9**	12.0 ± 6.3	15.8 ± 7.4**	16.9 ± 7.5**	13.5 ± 6.5**
	control group	10.3 ± 6.1	10.4 ± 6.0	9.6 ± 5.6	10.2 ± 5.9	10.4 ± 5.9	10.6 ± 6.3	10.1 ± 5.7
SBP (mmHg)	intervention group	119.7 ± 10.1	118.4 ± 9.1	114.1 ± 7.8*	119.6 ± 5.4	109.1 ± 8.8*	108.8 ± 6.1*	110.3 ± 7.5*
	control group	117.4 ± 5.7	115.7 ± 11.7	114.4 ± 10.1	115.7 ± 11.6	116.9 ± 7.4	114.9 ± 8.2	118.1 ± 7.8
DBP (mmHg)	intervention group	70.7 ± 7.5	72.0 ± 6.9	68.7 ± 5.9*	72.1 ± 4.8	66.4 ± 6.4*	64.7 ± 5.1*	67.0 ± 4.4*
	control group	69.3 ± 8.7	68.7 ± 8.5	70.3 ± 5.6	68.6 ± 6.3	69.9 ± 6.4	69.0 ± 4.7	69.7 ± 5.9
VO <sub>2</sub> max (ml/kg/min)	intervention group	27.1 ± 3.9	27.2 ± 3.7	27.5 ± 3.2	27.1 ± 3.6	27.3 ± 3.7	26.9 ± 3.1	27.4 ± 3.1
	control group	26.3 ± 3.8	26.3 ± 4.3	26.3 ± 3.1	26.9 ± 2.6	26.3 ± 2.6	27.4 ± 3.2	26.9 ± 3.3

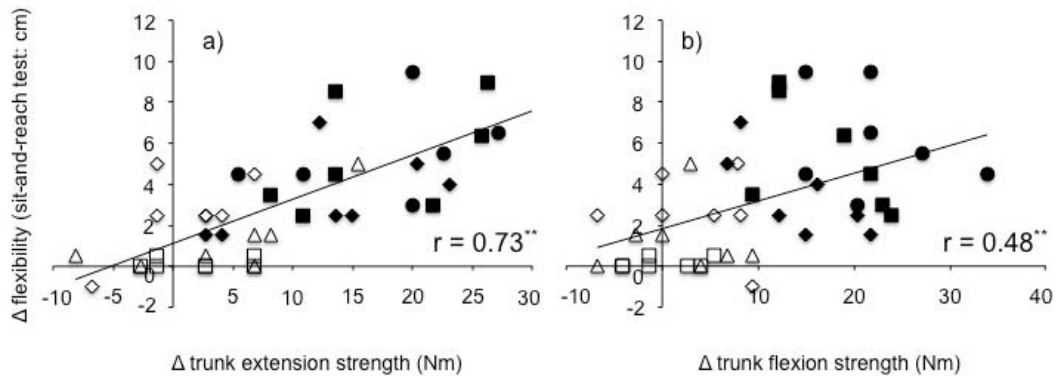




**Figure 3: Changes in muscle strength.** It is shown that changes in a) knee extension b) knee flexion c) trunk extension and d) trunk flexion strength respectively. The yellow markers indicate the SS phase. \*\*:p<0.01, significantly different from baseline.



**Figure 4:** Relationship (r-value based on Pearson product-moment correlation coefficient) of the amount of change between the flexibility and muscle strength in knee extension (a) and flexion (b). The markers are shown 1st (□), 2nd (◊), 3rd (△), 4th (▽), 5th (●), and 6th (◇), respectively. \*\*:p<0.01.



**Figure 5:** Relationship (r-value based on Pearson product-moment correlation coefficient) of the amount of change between the flexibility and muscle strength in trunk extension (a) and flexion (b). The markers are shown 1st (□), 2nd (◆), 3rd (△), 4th (■), 5th (●), and 6th (◇), respectively. \*\*:p<0.01.

in knee flexion strength and trunk extension strength were higher than knee extension strength and trunk flexion strength, respectively. A significant difference was not observed among the other parameters.

## Discussion

The purpose of this study was to evaluate the long-term and repeated bout effects of an SS program in older active adults and to clarify the effects of flexibility on muscle strength. We found that flexibility increased following the first SS intervention (period of 1 year), and as expected, muscle strength (flexion and extension of knee and trunk) were also affected. Additionally, a higher effect was obtained during the second SS intervention (period of 2 years), and at its conclusion, the effect of flexibility were maintained significantly. However, muscle strength was not possible to maintain the effects after each intervention ended. There was a significant correlation between the magnitude of changes in flexibility and muscle strength.

The intervention group increased their flexibility during the first SS intervention (31%), but the effects did not continue until the following year. Flexibility was further increased by the second intervention of the SS program, and the magnitude of change was significantly greater than the first intervention. According to a previous study [28], SS of the shortened muscles in older adults increased flexibility by increasing muscle length, possibly because of adaptation in the viscoelasticity of the connective tissue. Therefore, this may explain the increase in flexibility following the SS program. Previous animal studies have shown that stretching causes morphologic changes [33] in the shortened muscles and changes in the fiber gene expression. [34] There is also evidence that stretching can increase the length and number of serial sarcomeres. [35] Although these changes have not been observed in human muscles, the increase in flexibility of shortened muscles in older adults found after stretching in this study may also be a result of the increase in serial sarcomeres. Unfortunately, previous studies on the repeated bout effects of SS in the long-term do not exist. However, the repetition of SS has been reported to improve ROM [36, 37], and the effect of SS, which was measured by the sit and reach test, was maintained for 120 min. [38] Additionally, an SS program consisting of 4–8 weeks in older adults increased ROM significantly [28, 39–41]; furthermore, the results of the present study support the findings from a two-year follow-up study by Morey et al. [29] Therefore, the repeated bout effects of SS in the long-term may be a result of the increase in sarcomeres.

In this study, peak torque in muscle strength increased after SS program, and the increase in muscle strength was attributed to the increase in flexibility. The increase in torque after SS program intervention may also be a result from the increase in the activation threshold of the Golgi tendon organ (autogenic inhibition) and, as a consequence, the increase in the number of active motor units that can generate greater muscle tension after exercise. [42] Another factor that may be related to the increase in torque is muscle hypertrophy already observed in animal muscles after stretching sessions by the increase in the area and length

of the fibers. [35] Goldspink et al. [43] stated that the combination of contraction and stretching seems to have a greater effect on these adaptations. Kokkonen et al. [15] also verified that chronic stretching exercises of knee flexors and extensors by young individuals cause a 23.9% mean increase in muscle strength. They also suggest that there was muscle hypertrophy similar to that observed in animal muscles. Therefore, it is possible that the SS program in humans stimulates muscle adaptations similar to those observed in animals. However, only a regular exercise program by health class (3<sup>rd</sup> and 6<sup>th</sup> year in intervention group) were not sufficient to maintain the muscle strength gain produced by stretching. This result indicates that it is inadequate as general exercise for health class improves and/or maintains the muscle strength. In other words, it implies that there is a need to continuously perform the SS program. On the other hand, correlation coefficients in knee flexion strength and trunk extension strength were higher than knee extension strength and trunk flexion strength, respectively. As mentioned above, sit and reach test provides the sum of all joint angles as a composite test, but sit and reach test reflects the flexibility of the muscle group in the posterior body mainly (e.g., hamstring and/or trunk extension muscle group). [21] Therefore, it is considered that correlation coefficients in knee flexion strength and trunk extension strength were higher than knee extension strength and trunk flexion strength.

The subjects in both groups participated in health class, but the emphasis of these activities was on health maintenance or improvement. However, it might be expected that some parameters would worsen by aging throughout the 6-year period of this study [44, 45], but the all subjects (both groups) in this study, on average, parameters had better or maintained. Furthermore, subjects in both groups did not have to take medication on a regular basis during this period. These findings support several guidelines and reports, which indicated that an exercise program is important to older adults. [4–6, 16, 17, 19] However, it has been reported that increased flexibility in older adults is possible to improve the walk ability (gait and speed) [28, 39], but  $VO_2$ max did not change. This result indicates that it is inadequate as load for SS program improve the  $VO_2$ max. Our study design is likely to reflect the actual results of an SS program in older active adults, and our study findings indicated that a program designed to increase flexibility is useful for older adults (e.g., preventing sarcopenia). Concurrently, we demonstrated that for older adults, there is a need to continuously perform the SS program. We believe that the aspect of the SS program was important for increasing and maintaining flexibility in older active adults.

Limitations associated with the present approach are as follows. The first limitation is that measurement of sit and reach test is an indication of whole body. Especially, since flexibility is the sum of the range of motion of multiple, it was not possible to know the contribution rate of affect muscles in muscle strength. In this study, we were not able to examine in detail for flexibility by reason as time constraints and clinical context. In future research expects a detailed examination of flexibility, because there is a possibility to reduce the time of the SS program. The

second limitation is that subjects were chosen among older active adults. As described above, in this study, we have selected the older adults who already training in order to verify the true effects of SS program. Thus, the response against general older adults remains unknown. In fact, the effect of SS against general older adults has been many reported<sup>[4, 5, 28, 39-41]</sup>, and possibility of obtaining similar results is high.

In summary, this study evaluated the long-term and repeated bout effects of an SS program for a period of 1 to 2 years in older active adults and clarified the effects of flexibility on muscle strength (flexion and extension of knee and trunk). Flexibility was increased by the first SS intervention (period of 1 year), and a higher effect were obtained by the second SS intervention (period of 2 years). Additionally, we found a significant correlation between the magnitude of changes in flexibility and muscle strength. However, muscle strength was not possible to maintain the effects after each intervention ended. Therefore, these data provided further evidence that the repetition of an SS program is important for improving or maintaining flexibility and muscle strength in older active adults.

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