Accepted: 8 December 2017
DOI: 10.1111/sms.13039

ORIGINAL ARTICLE

WILEY

Slow movement resistance training using body weight improves muscle mass in the elderly: A randomized controlled trial

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Funding information
Ministry of Health, Labour and Welfare, Grant/Award Number: National Health Insurance Health up model project

To examine the effect of a 12-week slow movement resistance training using body weight as a load (SRT-BW) on muscle mass, strength, and fat distribution in healthy elderly people. Fifty-three men and 35 women aged 70 years old or older without experience in resistance training participated, and they were randomly assigned to a SRT-BW group or control group. The control group did not receive any intervention, but participants in this group underwent a repeat measurement 12 weeks later. The SRT-BW program consisted of 3 different exercises (squat, tabletop push-up, and sit-up), which were designed to stimulate anterior major muscles. Initially, these exercises were performed by 2 sets of 10 repetitions, and subsequently, the number of repetitions was increased progressively by 2 repetitions every 4 weeks. Participants were instructed to perform each eccentric and concentric phase of movement slowly (spending 4 seconds on each movement), covering the full range of motion. We evaluated muscle mass, strength, and fat distribution at baseline and after 12 weeks of training. Changes over 12 weeks were significantly greater in the SRT-BW group than in the control group, with a decrease in waist circumference, hip circumference, and abdominal preperitoneal and subcutaneous fat thickness, and an increase in thigh muscle thickness, knee extension strength, and hip flexion strength. In conclusion, relatively short-term SRT-BW was effective in improving muscle mass, strength, and fat distribution in healthy elderly people.

KEYWORDS
elderly, muscle mass, RCT trial, resistance training, sarcopenia, slow movement

1 | INTRODUCTION

Sarcopenia, age-related losses in the quantity of skeletal muscle mass as well as diminished muscle strength and/or physical performance, is associated with multiple adverse health consequences, including an increased risk of falls, fractures, and frailty, which can lead to a loss of independence and disability, increased morbidity and mortality, and reduced quality of life.[1-3] In recent years, increasing attention has been paid to resistance training as a useful adjunctive tool for increasing muscle mass and strength.[4-6] Resistance training programs in previous studies, however, required expensive exercise machines and supervised instruction.[5-7] For some elderly people, access to exercise facilities is limited and compliance may be poor. Furthermore, the load of resistance training is 60%-80% of one repetition maximum, which is stressful for knee and hip joints, especially in elderly people.

In contrast, resistance training using body weight as a load does not require special equipment or continuous supervision, and it can be performed conveniently at any time, any place, and in any weather. Moreover, the stress on the knee and hip joints is less than that on traditional high-load resistance training using machine and free weight. We have already reported that slow movement resistance training using body weight (SRT-BW) and a rubber tube as a load was effective in increasing muscle mass, lowering diastolic blood pressure, decreasing visceral fat, increasing the high-density lipoprotein cholesterol level, and decreasing triglyceride and hemoglobin A1c levels in healthy, non-obese elderly people.[8] However, the program consisted of 7 kinds of exercises, and it was a large burden for the elderly people to continue. Additionally, it was difficult for the elderly people to master the proper exercise technique of 7 kinds of exercises, and the research design was not a randomized controlled trial. In contrast, Watanabe et al[9] reported that SRT-BW and plyometric exercise significantly increased muscle strength but not muscle mass. Therefore, in this study, we conducted a randomized controlled trial to investigate whether 3 kinds of SRT-BW are effective for increasing muscle mass, muscle strength, and fat distribution in healthy elderly people.

2 | MATERIALS AND METHODS

2.1 | Subjects

All participants were local residents aged 70 years old or older who had received a medical checkup at a public health center. Fifty-three men and 35 women without experience in resistance training participated voluntarily in this research. Study participants were randomly assigned to the SRT-BW group or control group. The control group did not receive any intervention, but participants in this group underwent a repeat measurement 12 weeks later. All subjects underwent anthropometric measurements, physical examination, medical history assessment, living habits questionnaire, and resting and exercise electrocardiography (ECG). Subjects with cardiovascular disease (determined by a history or ECG findings), diabetes mellitus (determined by a history or fasting plasma glucose level >125 mg/dL), uncontrolled hypertension (blood pressure of 160/100 mm Hg with or without medication) were excluded from the study. No one was excluded from the study because of cardiovascular disease or diabetes mellitus. After being informed of the purpose of this study, all subjects gave their written informed consent. The study protocol was approved by the ethical committee of the Research Center of Health, Physical Fitness and Sports, Nagoya University, Aichi, Japan.

2.2 | Anthropometric data

Anthropometric measurements were obtained with the subjects in their underwear, without socks and shoes, and in a standing position. Height was measured to the nearest 0.1 cm with an electronic stadiometer. Body weight was measured to the nearest 0.1 kg using an electronic scale. Body mass index (BMI) was expressed as weight in kg/(height in m)^2. Waist circumference was measured to the nearest 0.1 cm at the umbilicus level. Hip circumference was measured to the nearest 0.1 cm at the greatest protrusion of the gluteal muscles. The right thigh circumference was measured to the nearest 0.1 cm at the midpoint between the greater trochanter and top of the patella. The sagittal abdominal diameter (SAD) was measured using a spreading caliper with subjects in the standing position. Subcutaneous fat thickness and muscle thickness at the right front thigh were also measured by B-mode ultrasonography (SSD-500, ALOKA, Aichi, Japan) with a linear-array probe (7.5 MHz). Anthropometric measurements were performed by a single experienced person (TK). Coefficients of variation in all measurements were less than 2.0%.

2.3 | Abdominal fat distribution

Abdominal fat distribution was assessed by B-mode ultrasonography (SSD-500, ALOKA) with a linear-array probe (5 MHz) using the method described by Suzuki et al.[10] Measurements were taken in the morning after an overnight fast at baseline, and it was repeated 5-7 days after the last exercise session to avoid any acute effects of SRT-BW. Subjects were in the supine position, with the probe held perpendicular to the skin on the upper median abdomen. Scanning was performed below the xiphoid process, and the surface of the liver was kept almost parallel to the skin while subjects held their breath. The minimum thickness of subcutaneous fat and maximum thickness of preperitoneal fat below the xiphoid process were measured, assuming that the latter was equivalent to the visceral fat area. Suzuki et al[10] reported a high correlation between the visceral fat area assessed by computed tomography and preperitoneal fat thickness assessed by ultrasonography ($r = .70$, $P < .001$). Subcutaneous fat thickness and muscle thickness at the right front thigh were also measured. Fat distribution measurements were conducted by a single experienced person (TK). Coefficients of variation in all measurements were less than 2.8%.

2.4 | Resistance training protocol

The SRT-BW program consisted of 3 different exercises (squat, tabletop push-up, and sit-up), which were designed to stimulate anterior major muscles. These exercises were initiated by performing 2 sets of 10 repetitions, and subsequently, the number of repetitions was increased progressively by 2 repetitions every 4 weeks. All exercises were performed with the participant's body weight serving as the load. Squats were performed with the subjects standing with their feet hip-width apart and toes pointed slightly outward. Then, they lowered their bodies by pushing their hips back and bending their knees to mimic sitting a chair until their thighs become parallel to the floor. From the lower position, they pushed up off their heels and slowly stood up. They were instructed to inhale when they lowered their body and exhale when they stood up. While squatting, the subjects' heads faced forward with their eyes straight ahead. The tabletop push-up was performed with subjects kneeling on the floor with their hands at shoulder level (all-fours position); they bent their elbows until their body almost touched the floor. Once their nose almost touched the floor, they slowly pushed up, with their elbows back to the starting position. They were instructed to inhale when they lowered their body and exhale when they pushed up. The sit-up was performed with subjects lying supine on the floor with their knees bent at 90°, and their hands were placed behind their neck. They raised their torso off the floor from a lying position as much as possible, without their feet being fixed. Subsequently, the torso was lowered to its original position, that is, until the back of their shoulders almost touched the floor. Subjects who could not raise their torso well were instructed to continue to apply effort. They were also instructed to inhale when they lowered their body and exhale when they pulled their torso upward.

The training sessions were performed everyday (once at the clinic, and then all other sessions were performed at home). At each clinic session, licensed supervisors instructed the participants to strictly follow the correct technique for each exercise movement so that the target muscles could be sufficiently stimulated. Participants were instructed to perform each eccentric and concentric phase of movement slowly (spending 4 seconds for each movement), covering the full range of motion. It took approximately 15 minutes. At home, participants performed these exercises in the same way as instructed at the clinic. During these exercises, the participants timed themselves. For some women who experienced difficulty performing the tabletop push-up and sit-up, we reduced the load by narrowing moving ranges instead of changing the number of repetitions. Each participant submitted a home-based training log at the time of the clinic sessions to ensure that all exercises were implemented as instructed.

2.5 | Muscle strength

Regarding muscle strength, hand grip strength, isometric knee extension, and hip flexion strength were measured. Hand grip strength was measured using a hand grip dynamometer (Grip-D; Takei Instruments, Niigata, Japan) while subjects were standing. Isometric knee extension and hip flexion strength were measured by the handheld dynamometer with a stabilization belt for measurement reliability (μTas, ANIMA, Tokyo, Japan). Subjects were instructed to extend their knee or flex their hip with maximum effort from a sitting position with the knee and hip joint at 90°. All measurements were taken twice on the right side, and the larger value was recorded. The intraclass correlation coefficients of hand grip, isometric knee extension, and hip flexion strength were 0.91, 0.96, and 0.84, respectively. All muscle strength measurements were conducted by a single experienced physical therapist.

2.6 | Physical activity and diet intake

The level of physical activity was evaluated for each participant by the average number of walking steps per day counted for 7 days using a pedometer (EM-180, Yamasa, Tokyo, Japan). Subjects were asked to put the pedometer on their waists while they were awake, except during water activities, and they were requested to record the number of steps taken every evening. On the basis of 3 continuous days of self-reported usual frequency and the portion of food intake, the total energy intake was estimated by dietitians using diet analyzing software (Health Make Program, Health Make System Research center, Yokohama, Japan). Furthermore, the 2 groups of subjects were instructed not to change their usual exercise and eating patterns during the study period.

2.7 | Statistical analyses

All data are expressed as a mean (standard deviation). The statistical significance of the difference in each parameter between the SRT-BW and control groups at baseline was determined using the unpaired *t* test. Differences at 12 weeks of the intervention were calculated by subtracting the within-group changes from baseline for the control group from the within-group changes for the SRT-BW group. For each variable, significance of between-group differences in changes over 12 weeks was examined using two-way analysis of variance, which included sex as a covariate. A possible interaction of sex between the groups was also examined. A *P*-value $<.05$ was considered statistically significant. The analyses were performed using JMP11 (SAS Institute Inc., Cary, NC, USA).

3 | RESULTS

The average rate of attendance at the supervised training session was 91%. In addition, the median exercise frequency confirmed by training logs was 5 days at home. Two men in the SRT-BW group dropped out of the study. Table 1 shows subjects' characteristics at baseline.

There was no significant difference at baseline in any of the variables between the SRT-BW and control groups, except for the thigh circumference and thigh muscle thickness. Table 2 shows absolute changes from baseline for the SRT-BW and control groups, and differences between these groups.

Changes over 12 weeks were significantly greater in the SRT-BW group than in the control group for the following measurements: the BMI, waist circumference, hip circumference, SAD, abdominal subcutaneous fat thickness, abdominal preperitoneal fat thickness, thigh circumference and fat thickness decreased, whereas the thigh muscle thickness,

TABLE 1 Baseline characteristics of subjects

	SRT-BW	Control
Number of subjects	42	44
Sex (M/F)	25/17	26/18
Mean age (yr)	72.5 (2.1)	73.2 (2.1)
Total energy intake (kcal)	2195.8 (529.1)	2101.7 (556.1)
Walking steps (steps/day)	7000.0 (3402.1)	7108.6 (3300.8)
Body weight (kg)	57.2 (9.9)	55.7 (9.6)
BMI (kg/m^2)	23.2 (2.6)	22.4 (2.4)
Waist circumference (cm)	87.4 (7.4)	85.6 (8.2)
Hip circumference (cm)	90.5 (5.0)	88.8 (4.4)
SAD (cm)	21.5 (2.8)	20.9 (3.1)
Abdominal subcutaneous fat thickness (mm)	13.3 (4.6)	12.7 (3.4)
Abdominal preperitoneal fat thickness (mm)	8.7 (3.0)	7.8 (3.0)
Thigh circumference (cm)*	50.9 (3.6)	49.3 (3.6)
Thigh muscle thickness (mm)*	38.5 (6.1)	35.8 (5.9)
Thigh fat thickness (mm)	8.3 (3.4)	7.5 (2.2)
Right grip strength (kg)	26.8 (8.4)	26.4 (7.8)
Right hip flexion strength (kg)	19.7 (6.2)	20.3 (5.9)
Right knee extension strength (kg)	29.4 (12.4)	30.1 (10.3)

SRT-BW, Slow movement resistance training using body weight; BMI, Body mass index; SAD, Sagittal abdominal diameter.
Data presented by mean (standard deviation).
*At baseline, there were no significant differences in all parameters between RT-BW and control groups except thigh circumference and thigh muscle thickness ($P < .05$).

hip flexion strength, and knee extension strength increased. However, there were no significant differences between the SRT-BW and control groups in changes over 12 weeks for body weight, grip strength, total energy intake, and walking steps.

4 | DISCUSSION

Resistance training programs in previous studies required expensive exercise machines and supervised instruction. However, results of the present study suggest that SRT-BW is also effective for increasing muscle mass and strength, and improving fat distribution in healthy elderly people. Additionally, we provided evidence that thigh muscle thickness significantly increases only in SRT-BW. Our previous study[8] and others[11,12] have found that slow movement resistance training was useful for hypertrophy. For example, we examined the effect of a 12-week SRT-BW with 7 kinds of exercises on body composition and fat distribution in elderly people. Healthy, nondiabetic, elderly volunteers (22 men and 30 women) aged 65-82 years were nonrandomly divided into an SRT-BW (12 men and 20 women) or control (10 men and 10 women) group.[8] Subjects in the SRT-BW group were trained 3 times per week for 12 weeks according to a specified protocol involving a combination of upper and lower body weight and rubber tubing exercises. Changes over 12 weeks were significantly greater in the training group than in the control group, with a decrease in waist circumference, preperitoneal (visceral) fat thickness, and thigh fat thickness, and an increase in thigh muscle thickness. Yet, there was no significant change in body weight, fat mass, and fat-free mass between the groups. Relatively short-term SRT-BW was effective for improving muscle mass and fat distribution in healthy elderly people without weight loss.

The intensity of resistance training using body weight as a load is considered lower than that of traditional high-load resistance training using machine and free weight. As it is impossible to assess the intensity of resistance training using body weight as a load, we cannot directly compare our study's results with those using exercise machines or free weights. However, the speed of resistance training performance may exert a significant effect independently of the intensity of exercise. Burd et al[13] reported that a leg extension exercise at 30% of one repetition maximum with a slow lifting movement (6 seconds up and 6 seconds down) contributed to myofibrillar protein synthesis in young men. They also reported that the myofibrillar protein synthesis rate in slow lifting movement was higher than that of in normal speed (1 second up and 1 second down). In our study, participants were instructed to perform each eccentric and concentric phase of movement slowly, spending 4 seconds on each movement to cover the full range of motion. Although the time duration was 4 seconds and not 6 seconds, the effects of 3 exercises in our study may be as strong as those of high-intensity resistance training at normal speed, if the findings in Burd et al's study[13] are applicable to other muscles. A significant increase in thigh muscle thickness in our study may support this interpretation.

Although the present study's findings showed that SRT-BW is effective for increasing muscle mass, Watanabe et al[9] reported that resistance training using body weight with slow speed movement and tonic force generation (3-second eccentric, 3-second concentric, and 1-second isometric actions with no rest between each repetition) improved physical function and strength but not muscle mass. Holm et al[14] reported that even with low-load resistance training (15.5% of one repetition maximum), a long total contraction time is related to the activation of motor units, which increases muscle size and strength. This result suggests that a long total contraction time is important for

TABLE 2 Changes in the measured variables over 12-week intervention for the RT-BW and control groups, and differences in those changes between groups

	Changes from baseline levels		Between- group differences in changes from baseline levels (95% confidence interval)
	SRT-BW (n = 42)	Control (n = 44)	
Total energy intake (kcal)	−42.3 (496.4)	−3.8 (494.7)	−38.5 (−253.6 to 176.7)
Walking steps (steps/day)	−16.9 (2644.6)	−458.4 (2851.9)	441.5 (−753.0 to 1637.0)
Body weight (kg)	−0.5 (1.0)**	−0.2 (0.9)	−0.4 (−0.8 to 0.0)
BMI (kg/m^2)	−0.3 (0.4)***	−0.1 (0.4)	−0.2 (−0.3 to 0.0)†
Waist circumference (cm)	−1.1 (1.2)***	−0.2 (0.5)*	−0.9 (−1.3 to −0.6)†††
Hip circumference (cm)	−0.7 (0.2)***	−0.1 (0.1)	−0.6 (−0.9 to −0.2)††
SAD (cm)	−0.5 (0.5)***	−0.1 (0.3)	−0.4 (−0.6 to −0.3)†††
Abdominal subcutaneous fat thickness (mm)	−0.5 (0.9)**	0.0 (0.9)	−0.5 (−0.9 to −0.1)†
Abdominal preperitoneal fat thickness (mm)	−0.5 (0.8)***	−0.2 (0.6)	−0.3 (−0.6 to −0.1)†
Thigh circumference (cm)	−0.2 (0.4)**	−0.1 (0.2)	−0.1 (−0.3 to 0.0)†
Thigh muscle thickness (mm)	1.0 (1.4)***	−0.1 (0.3)	1.0 (0.6 to 1.5)†††
Thigh fat thickness (mm)	−0.5 (1.0)**	0.1 (0.2)	−0.5 (−0.9 to −0.2)†††
Right grip strength (kg)	0.7 (3.1)	0.3 (3.8)	0.4 (−1.1 to 1.8)
Right hip flexion strength (kg)	1.8 (3.2)***	−0.3 (2.9)	2.1 (0.8 to 3.4)††
Right knee extension strength (kg)	4.5 (4.2)***	1.2 (4.5)*	3.2 (1.4 to 5.1)†††

SRT-BW, Slow movement resistance training using body weight; BMI, Body mass index; SAD, Sagittal abdominal diameter.
Data presented by mean (SD). A positive sign indicates an increase, and a negative sign indicates a decrease.
***$P < .001$, **$P < .01$, *$P < .05$ within-group change from baseline.
†††$P < .001$, ††$P < .01$, †$P < .05$ between-group difference in change from baseline.

increasing muscle mass. In terms of the quadriceps, squat and split squats are suitable for increasing muscle mass. The total contraction time of the quadriceps (squat and split squats) in Watanabe et al's study was 315 seconds per week (15 repetitions × 7 seconds × 1 set × 3 times per week). In contrast, a total contraction time of the quadriceps (squat) in our study was 1344 seconds per week (12 repetitions × 8 seconds × 2 sets × 7 times per week). The 4.3 times (1344 seconds/315 seconds) higher total contraction time on the quadriceps may have affected the increasing muscle mass.

Our study found significant increases in the knee extension strength and hip flexion strength only in the SRT-BW group. Knee extension strength gain may occur due to squat and hip flexion strength gain, which may occur after doing sit-ups. These strength gains will contribute to preventing frailty and falls. In contrast, grip strength did not significantly change in both groups. These 3 kinds of SRT-BW did not focus on the forearm muscle, which relates to grip strength. This result suggests that the training effects only appear at specific site, and SRT-BW as well as high-intensity resistance training can contribute to strength gain.

Our study also found beneficial effects of SRT-BW on fat distribution (abdominal preperitoneal fat, abdominal subcutaneous fat, and thigh fat thickness) without significant changes in energy intake and walking steps. These results are consistent with those of our previous research study, which found that 7 kinds of SRT-BW were useful for improving abdominal preperitoneal fat thickness and thigh fat thickness.[8] Treuth et al[15] performed a study using exercise machines with moderate intensity (67% of 1 repetition maximum) for 16 weeks in healthy older women. They found significant reductions in intra-abdominal adipose tissue and thigh fat. Although exercise machines were used, these results suggest that SRT-BW is useful for people who cannot walk for a long time because of arthritis. Furthermore, as 3 kinds of SRT-BW do not require much time, these exercises may be easy for busy people to continue performing.

There are several limitations in the present study, including the small sample size and relatively short-term intervention. Additionally, the study subjects were considered highly motivated elderly persons, so generalizability of the results needs to be verified using larger population-based samples.

In conclusion, even a relatively short-term SRT-BW with 3 kinds of exercises was effective in increasing muscle mass and strength, and improving fat distribution in healthy elderly people.

5 | PERSPECTIVE

SRT-BW with 3 kinds of exercises was effective in increasing muscle mass and strength and improving fat distribution in healthy elderly people. Furthermore, resistance training using body weight as a load does not require special equipment or continuous supervision, and it can be performed conveniently at any time, any place, and in any weather. Moreover, stress on knee and hip joints is less than that on traditional high-load resistance training using machine and free weight. These characteristics suggest that SRT-BW is a useful tool for preventing sarcopenia and osteoarthritis in elderly people.

ACKNOWLEDGEMENTS

The author wishes to thank Yokkaichi City for supporting this project. This project was supported by a grant from the Japan Ministry of Health, Labour, and Welfare for National Health Insurance Health-Up Model Project. The funder had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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How to cite this article: Tsuzuku S, Kajioka T, Sakakibara H, Shimaoka K. Slow movement resistance training using body weight improves muscle mass in the elderly: A randomized controlled trial. *Scand J Med Sci Sports*. 2018;28:1339–1344. https://doi.org/10.1111/sms.13039