

Effects of Body-weight Squat Training on Muscular Size, Strength and Balance Ability in Physically Frail Older Adults

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The purpose of this study was to evaluate the effects of a 12-week group-based body-weight squat training program on muscle mass, muscle strength, and balance in physically frail community-dwelling older men and women. Fifteen older adults (mean age = 78.7 yr) who needed assistance performing activities of daily living (ADL) according to long-term care insurance regulations in Japan participated in the study. Participants performed squat exercise in a group-setting using body-weight as resistance while singing for one set consisting of 48 reps twice weekly for 12 weeks. Body mass, thigh girth, thigh muscle thickness assessed by B-mode ultrasound, knee extension torque (KET), static and dynamic balance (static (SB): sway velocity (SV) standing on firm or foam surfaces with eyes open or closed; dynamic (DB): limits of stability) were measured before and after the intervention. Following the intervention, participants significantly ($P < 0.05$) decreased body mass and increased KET relative to body mass. Although thigh girth did not change, thigh muscle thickness did increase. There were no appreciable changes in DB nor in SB, except SV standing on a firm surface with the eyes open improved. Group-based body-weight squat exercise in physically frail older adults improves muscle mass and strength but has little effect on balance parameters.

Keywords: Body-weight squat training, specificity of exercise, frail older adults

1. Introduction

With a rapidly growing older population, loss of independence has become a serious problem in Japan as well as around the world. This has led to a growing number of adults requiring long-term care that imposes medical expenses and social burdens.

One quality for successful aging is the ability to independently perform activities of daily living (ADL) such as standing from a seated position, walking, and climbing stairs (Hazell, et al., 2007). Because muscle weakness and poor balance are associated with an increased risk of disability (Guralnik

et al., 1995) and falls (Tinetti et al., 1986), many exercise programs have been developed to improve these capacities in older adults (Chang et al., 2004; Faber et al., 2006; Hauer et al., 2003; Islam et al., 2004). Additionally, several studies have shown that resistance exercise, particularly machine-based exercise and/or using dumbbells or free weights, is beneficial for frail older adults as well as healthy older adults (Fiatarone, et al., 1994; Mihalko and McAuley, 1996). However, it is typically not feasible to have large, expensive training equipment in day service centers that provide care for older adults. Previous research has shown that training with

ankle-weight cuffs and resistance bands, or using participants' body weight as resistance, to be effective but no details were provided regarding the exercise intensity used in these interventions (Yamauchi et al., 2005; Rosie and Taylor, 2007; Shaw and Snow, 1998; Takeshima et al., 2013; Yoshitake et al., 2011).

Recently, we reported that the activity level of the quadriceps femoris during a body mass-based squat movement is influenced by its force generation capability (Fujita et al., 2011). For individuals with a knee extension torque (KET) relative to body mass less than 1.9 Nm/kg^{-1} , body mass-based squat movement is considered to be a fairly high-intensity activity. The breakpoint of 1.9 Nm/kg^{-1} may be assumed to be a threshold level of knee extensor strength, which should be maintained to perform ADL without great difficulty. Although, body mass-based squat movement seems of adequate exercise intensity for frail older adults, little is known about the effects of long-term training using this activity.

Age-related loss in knee extensor strength increases the difficulty of performing ADL, such as walking, rising, and stepping (Hortobágyi et al., 2003) and the risks of falling and associated fracture (Wolfson et al., 1995; Kirkendall and Garrett, 1998). Moreover, a sit-to-stand movement like squatting requires greater muscle strength than other daily activities, such as walking or stair climbing (Ploutz-Snyder et al., 2002; Yoshioka et al., 2007). Therefore, the development of an effective intervention that targets the knee extensors would be of benefit to frail older adults.

Despite the known benefits of exercise in maintaining independence, participation rates are not high among all age groups (Ashworth et al., 2005). Previous studies have used home-based exercise programs that can be less costly and do not require participant transportation but program adherence and appropriate exercise progression can be problematic (Olson et al., 2011). Older adults value the sense of fulfillment provided by the social interactions with the other participants, as well as the support and encouragement received from the group (Dionigi, 2007; Layne et al., 2008). In addition, the social support given in group-based programs can counteract the isolation that older adults often experience, and companionship during activities improves physical activity among older adults (Layne et al., 2008; Shores et al., 2009). Furthermore, those who re-

ported high enjoyment in physical activity were more likely to report higher levels of activity (Salmon et al., 2003).

The purpose of this study was to evaluate changes in muscle strength, muscle mass, and balance in physically frail community-dwelling older men and women following a 12-week group-based exercise program consisting of squat exercise using participants' body weight as resistance while singing together.

2. Methods

2.1. Participants and exercise program

Fifteen older adults (6 males and 9 females) who needed assistance performing ADL according to long-term care insurance regulations in Japan participated in the study. The means and standard deviations (SDs) of age, height, and body mass for the participants were 78.7 ± 4.1 years, 151.5 ± 8.7 cm, 57.4 ± 11.4 kg, respectively. Height was measured using a digital stadiometer (DSN-90, Muratec-KDS, Kyoto, Japan) to the nearest 0.1 cm. Body weight was measured to the nearest 0.1 kg using a digital scale (HBF-214, Omron, Tokyo, Japan). **Table 1** shows nursing care levels and presence of diseases at pre-testing.

The ethical committee of the National Institute of Fitness and Sports in Kanoya approved the study. All participants received written and oral instructions for the study and each gave their written informed consent prior to participation.

All participants performed the squat exercise using body-weight as resistance for one set of 48 reps while singing together on 2 days per week for 12 weeks. Starting in the seated position, participants completed 48 reps by continuously standing from and sitting in a standard chair (seat height 43 cm) (**Figure 1**). Each full repetition took approximately 4 sec with the entire set being completed in approximately 3.5 min. Based on the work of Fukunaga (2006), participants sang traditional songs while performing the exercise. The goal of this was to prevent the Valsalva maneuver and to create an atmosphere of happiness.

2.2. Testing

Measurements included body mass, thigh girth,

Table 1 Characteristics of Participants

Participants	Sex	Nursing care level	pressure of disease
A	m	S1	asthma, osteoporosis
B	m	S2	lumbar canal stenosis
C	m	L1	parkinson disease
D	m	S1	hypothyroidism, lumbar spondylosis
E	m	L2	brain infaction (right hemiplegia), angina pectoris, cervical spondylotic myelopathy
F	m	L1	diabetes, hypertension, kidney disease (requiring dialysis)
G	f	S2	diabetes, angina pectoris, ossification of the posterior longitudinal ligament
H	f	L1	lumbar spondylolisthesis
I	f	S2	parkinson disease, diabetes, osteoporosis
J	f	S2	femoral neck fracture (femoral head replacement), diabetes, hypertension
K	f	S1	parkinson disease
L	f	L1	brain infaction (left hemiplegia), lung cancer
M	f	S1	lumbar spondylosis, knee osteoarthritis
N	f	S1	diabetes (retinopathy and peripheral neuropathy), cerebral infarction sequelae
O	f	S2	diabetes, hypertension, epilepsy, thoracic compression fracture, cerebral infarction sequelae

Note: m: male, f: female, S: support required level 1 and 2 (Those who need no continuous care but need some support in daily life such as help with dressing themselves), L: long-term care required for their daily living level 1-5 (Those who need continuous care because of being bedridden, dementia, etc.)



Figure 1. Body-weight squat exercise
Body-weight-squat exercise using a standard chair (seat height 43 cm).

anterior thigh muscle thickness, isometric maximal knee extension torque, and static and dynamic balance (static (SB): sway velocity (SV) standing on firm or foam surfaces with eyes open or closed; dynamic (DB): limits of stability). These measurements were conducted before and after the 12-week intervention. Throughout the study, the same technician conducted all data collection and analysis.

2.3. Method for measurement

2.3.1. KET

KET during isometric maximal voluntary contraction (MVC) was measured using a specially designed dynamometer (Takei, Niigata, Japan) with tension / compression load cells (LUR-A-SAI, Kyowa, Tokyo, Japan). The right leg was measured for all participants. The participants sat on the dynamometer at 90 degrees of hip and knee joint flexion (full

extension = 0 degree). The participant's hip was fixed by a non-elastic belt to prevent postural change. Torque data from each trial were amplified using a strain amplifier (DPM-751A, Kyowa, Tokyo, Japan). The torque signals obtained via a 16-bit analog / digital converter (PowerLab/16s, AD Instruments, Sydney, Australia) were recorded on a personal computer at a sampling frequency of 1 KHz. Participants gradually exerted muscle force from rest to maximum over 5 sec and then sustained maximal exertion for approximately 2 sec. Before the maximal testing, participants were asked to exert submaximal muscle force to become familiar with the test procedure. Participants performed 2 trials with a 3-min rest between trials to exclude the influence of fatigue. The highest value among the trials was used for analysis. The KET was expressed relative to body mass (KET/BM). This procedure has been described by Fujita et al. (2011) and

Yoshitake et al. (2011).

2.3.2. Muscle thickness (MT)

MT of the anterior thigh was measured as the distance between the fat-muscle tissue and muscle-bone interface by a B-mode ultrasound (Mirucube, Global health, Kanagawa, Japan) with a linear scanner. The right leg was measured for all participants. During ultrasound measurements, participants remained in a standing position with their legs and arms straight and muscles relaxed as described previously (Ishida et al., 1995). The anthropometric location of the measurement site was precisely located and marked on the anterior surface at the midline of the femoral length (the distance from the greater trochanter of the femur to articular cleft between the femur and tibial condyles). A transducer with a 6MHz scanning head was placed perpendicular to the underlying muscle and bone tissues. The scanning head was coated with ultrasonic gel, which provided acoustic contact without depressing the dermal surface. The ultrasonographic images were analyzed by dedicated analytical software (Mirucube Y ver. 1.0, Global health, Kanagawa, Japan). MT was measured to the nearest 0.1 mm. One examiner performed the muscle thickness measurements throughout this study (**Figure 2**). The measurements were taken with a vernier caliper to the nearest 0.1 mm. The intraclass correlation coefficients for the tissue thickness measurements on two different days were 0.99 to 1.00 for MT (Takeshima et al., 2014). The accuracy and test-retest repeatability of the muscle thickness measurements have also been established in prior studies (Miyatani et al., 2003; Sanada, et al., 2006).

2.3.3. Static (SB) and dynamic (DB) balance tests

A Balance Master Platform System (NeuroCom International, Oregon, USA) was used to measure SB and DB (Rogers et al., 2003). SB measures were taken while standing on different surfaces with the eyes open or closed, and on different of surface conditions (firm or with foam pad). In this study, the Clinical Test of Sensory Interaction for Balance using the Balance Master Platform System was used as a test of postural SV that was designed to measure the influence of sensory input on balance (Nashner and McCollum, 1985). Composite SV (SVcomp) scores were calculated based on each sway velocity condition as an index of SB. The test required the participant to stand: (a) on a flat surface with the eyes open (SVcomp1); (b) on a flat surface with the eyes closed (SVcomp2); (c) on thick foam with the eyes open (SVcomp3); and (d) on thick foam with the eyes closed (SVcomp4). The force platform was marked to maintain consistency in foot placement. For each stance, the participant stood with their eyes at the horizon and their arms at the sides in a neutral position. Trials required 10 sec of data collection (**Figure 3-a**).

DB was determined using the limits of stability (LOS) assessment in which 8 targets appeared around a center square at 0 (forward), 45, 90 (right), 135, 180 (back), 225, 270 (left), and 315 degrees (**Figure 3-b**). Center of pressure (COP) appeared on a monitor as a human-shaped cursor and moved as participants shifted their weight toward an identified target, holding the position for 5 sec. Each LOS trial measured endpoint (EPE) and maximum excursion (MXE). EPE ends when the COP movement first ceases progression toward the target. EPE was ex-

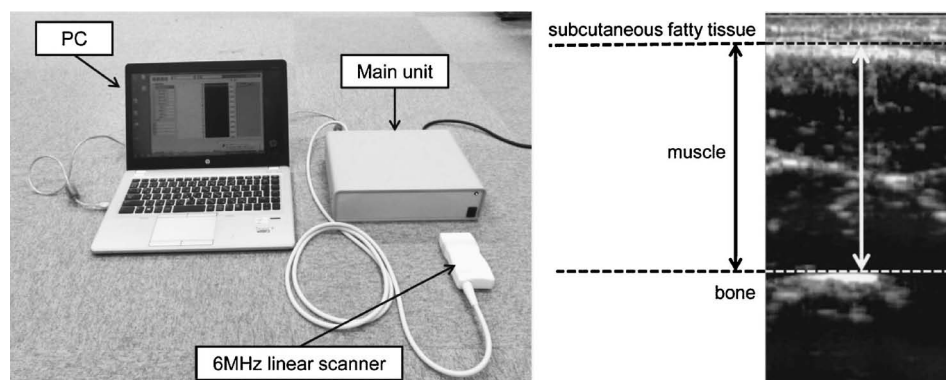


Figure 2. Thigh muscle thickness assessed by B-mode ultrasound
Muscle thickness of the anterior thigh was measured as the distance between the fat-muscle tissue and muscle-bone interface by a B-mode ultrasound with a 6 MHz linear scanner.

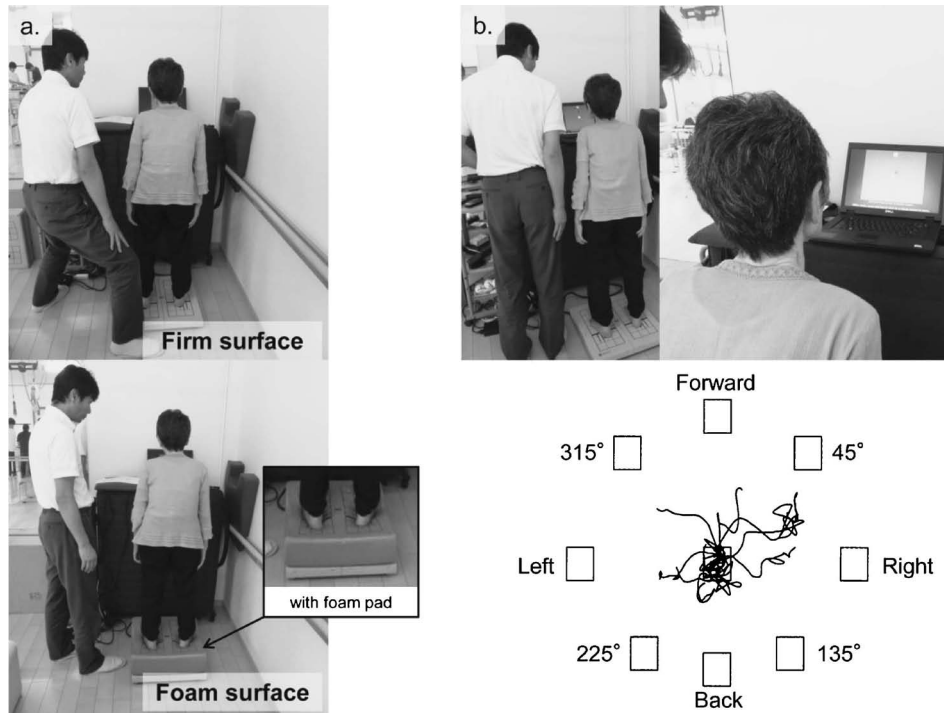


Figure 3. Static and dynamic balance tests with the Balance Master Platform System

Static balance was quantified using postural sway velocity while standing on different surfaces (firm or with foam pad) with the eyes open or closed (a). Dynamic balance was determined using the limits of stability assessment in 8 directions located around a center target as the starting point at 0 (forward), 45, 90 (right), 135, 180 (back), 225, 270 (left), and 315 degrees (b).

pressed as a percentage of the distance to the target. Hence, a participant whose initial movement ends precisely at the target had an EPE of 100%. When initial attempts were substantially short of the target, most people initiated additional movements after the EPE was recorded. To represent this additional movement and COP excursion, an additional measurement, the MXE was used. The MXE was the maximum distance the COP was displaced toward the target over the entire duration of the trial (Rogers, et al., 2003). MXE was also expressed as a percentage of the distance to the target. Four directions (forward, back, right and left) and composite EPE and MXE scores were calculated based on movements toward all 8 targets. These scores of reaction time (RT), movement velocity (MVL), and directional control (DC) were also used. RT was time in seconds between the signal to move and the initiation of movement. MVL was body tilt velocity and calculated based on the average speed of COP movement between 5% and 95% of the distance to the primary endpoint using one's height as a reference and expressed in degrees per sec. Directional control, expressed as percent, was based on 100%

being a straight line from the initial center of pressure to the intended target. Because the participants were asked to move quickly, rapid reaction time and greater speed was desirable, but participants must also have been able to control the movement in the intended direction.

The SB and DB tests were administered in a single testing session on the same days. A 3-minute rest interval was provided between each test. Following verbal instruction and demonstration by the tester, participants completed one practice trial and one test trial while barefoot. There were no unsuccessful trials for these tests.

2.4. Statistical analysis

Descriptive data are expressed as means and standard deviations (SDs). Pre- and post-test comparisons were performed using dependent t-tests. Effect size [ES] was also calculated for each test. Cohen's definition of small, medium and large ESs (ES = 0.2, 0.5, and 0.8, respectively) was used (Cohen, 1988). A probability value of less than 0.05 was considered statistically significant. All data were analyzed using

SPSS ver. 15.0 for Windows statistical software (SPSS Inc., Tokyo, Japan).

3. Results

All participants continued the current exercise program with no incidence of injury during the study and no participant declined to participate in the intervention. Mean attendance rate for this exercise group was 93.1%.

Following the intervention, participants significantly ($P < 0.05$) decreased body mass by 1.6% (57.4 ± 11.4 to 56.5 ± 11.1 kg, $ES = 0.53$), and significantly increased KET by 9.8% (67.3 ± 21.1 to 73.9 ± 24.0 Nm, $ES = 0.63$) and KET/BM by 10.9% (1.19 ± 0.34 to 1.32 ± 0.38 Nm/kg, $ES = 0.69$) (Table 2). However, there were no significant correlation between KET/BM before the intervention and the relative changes after the intervention. Apart from that, thigh girth did not change, thigh muscle thickness significantly increased by 6.2% (29.2 ± 5.8 mm to 31.0 ± 5.4 mm). There were no appreciable changes in DB nor in SB. However, SV standing on a firm surface with the eyes open improved by 26.2% (0.42 ± 0.25 to 0.31 ± 0.13 mm/sec) (Tables 3 and 4).

Table 2 Body mass, thigh girth, muscle thickness, and strength at pre- and post- assessment

Measurements	Pre-	Post-	p-value	ES
Body mass (kg)	57.4 ± 11.4	56.5 ± 11.1	0.036*	0.53
Thigh girth (cm)	44.6 ± 4.3	44.4 ± 4.1	0.328 (n.s.)	0.26
MT (mm)	29.2 ± 5.8	31.0 ± 5.4	0.007**	0.65
KET (Nm)	67.3 ± 21.1	73.9 ± 24.0	0.010**	0.63
KET/BM (Nm/kg)	1.19 ± 0.34	1.32 ± 0.4	0.003**	0.69

Note: MT: muscle thickness, KET: knee extension torque, KET/BM: KET relative to body mass, **: $P < 0.01$, *: $P < 0.05$, n.s.: not significant

Table 3 Static balance at pre- and post- assessment

Measurements	Pre-	Post-	p-value	ES
EO-Firm (deg/sec)	0.41 ± 0.26	0.31 ± 0.13	0.042*	0.51
EC-Firm (deg/sec)	0.57 ± 0.22	0.57 ± 0.23	0.705 (n.s.)	0.10
EO-Foam (deg/sec)	1.24 ± 0.79	1.03 ± 0.40	0.129 (n.s.)	0.41
EC-Foam (deg/sec)	3.94 ± 1.90	3.96 ± 1.57	0.969 (n.s.)	0.11

Note: EO: eyes open, EC: eyes closed, Firm: firm surface, Foam: foam surface, *: $P < 0.05$, n.s.: not significant

4. Discussion

The purpose of the present study was to evaluate the effects of a 12-week group-based body-weight squat exercise program on muscle mass, muscle strength, and balance in physically frail community-dwelling older men and women. The 12-week program significantly decreased body mass by 1.6% ($ES = 0.53$), increased KET by 9.8% ($ES = 0.63$), and increased KET/BM by 10.9% ($ES = 0.69$). Moreover, although thigh girth did not change, thigh muscle thickness did increase by 6.2% ($ES = 0.65$). These results suggest that performing chair squat using body-weight as resistance is effective in improving muscular strength and muscle mass in physically frail older adults.

A government-supported nursing-care insurance system exists in Japan that provides inexpensive care to older adults who utilize the program. Although it is a good system, it does not entail a component of physical activity as exercise machines are expensive and space is limited in day centers and nursing homes. The results of the present study suggest that an exercise program consisting of body-weight exercises is effective in improving strength and therefore could be incorporated into this system as it is inexpensive and requires only a chair.

Mean attendance rate for the exercise group was 93.1%. Previous studies have suggested that 50% of people who begin an exercise program discontinue within 6 months (Hong et al., 2008; Medina-Mirapeix et al., 2009; Kallings, et al., 2009). An adherence level of at least 80% to 85% is recommended if an intervention is to have a meaningful effect and therapeutic value (Pisters et al., 2010). Although the present study was only 12 weeks in duration, it appears that adherence was sufficiently high and may be, in part, attributed to the incorporation of group-based exercise that incorporated singing. Further study is needed to assess the psychological parameters that contribute to the high attendance associated with this program.

In general, the relative improvement ratio from training can be considered to have greater impact on muscle in participants with low fitness levels, such as those in this study, as they are starting at a functional level at which they have difficulty performing activities of daily living. In addition, Fujita et al. (2011) reported that the activity level of the quadriceps femoris during body-weight-based squat

Table 4 Dynamic balance at pre- and post- assessment

Measurements		Pre-	Post-	p-value	ES
RT (sec)	Forward	1.22 ± 0.42	0.95 ± 0.27	0.058 (n.s.)	0.48
	Back	0.95 ± 0.40	0.87 ± 0.25	0.205 (n.s.)	0.34
	Right	1.08 ± 0.41	0.95 ± 0.34	0.232 (n.s.)	0.06
	Left	1.04 ± 0.50	0.92 ± 0.29	0.447 (n.s.)	0.21
	Comp	1.07 ± 0.37	0.92 ± 0.24	0.118 (n.s.)	0.41
MVL (deg/sec)	Forward	2.06 ± 0.69	2.16 ± 0.74	0.655 (n.s.)	0.12
	Back	1.43 ± 0.70	1.87 ± 0.75	0.036*	0.53
	Right	3.11 ± 1.28	3.91 ± 2.06	0.200 (n.s.)	0.05
	Left	2.91 ± 1.46	3.17 ± 1.01	0.551 (n.s.)	0.16
	Comp	2.39 ± 0.91	2.78 ± 0.96	0.236 (n.s.)	0.31
EPE (%)	Forward	44.13 ± 15.84	45.67 ± 11.39	0.651 (n.s.)	0.12
	Back	37.40 ± 16.75	39.93 ± 16.51	0.522 (n.s.)	0.17
	Right	64.53 ± 19.31	77.73 ± 20.56	0.039*	0.52
	Left	62.87 ± 19.24	71.47 ± 18.99	0.186 (n.s.)	0.35
	Comp	52.33 ± 14.20	59.00 ± 11.97	0.073 (n.s.)	0.46
MXE (%)	Forward	60.60 ± 14.62	60.87 ± 16.51	0.929 (n.s.)	0.24
	Back	49.00 ± 20.54	54.93 ± 19.28	0.206 (n.s.)	0.34
	Right	84.67 ± 17.12	96.13 ± 17.92	0.022*	0.57
	Left	81.00 ± 20.48	86.93 ± 18.53	0.297 (n.s.)	0.28
	Comp	68.87 ± 15.13	74.87 ± 12.94	0.065 (n.s.)	0.47
DCL (%)	Forward	77.73 ± 9.68	71.60 ± 13.72	0.094 (n.s.)	0.43
	Back	59.20 ± 23.45	63.73 ± 18.37	0.063 (n.s.)	0.48
	Right	74.27 ± 11.40	74.80 ± 8.16	0.784 (n.s.)	0.08
	Left	70.60 ± 14.78	72.00 ± 10.41	0.707 (n.s.)	0.10
	Comp	70.60 ± 12.84	70.60 ± 9.18	1.000 (n.s.)	0.00

Note: RT: reaction time, MVL: movement velocity, EPE: endpoint excursion, MXE: maximum excursion, DCL: directional control, Comp: composite value, *: $P < 0.05$, n.s.: not significant

movement is influenced by the force generation capability during the squat movement. For individuals with a KET/BM less than 1.9 Nm/kg, body-weight-based squat movement is considered to be a high-intensity activity. All of the participants in the present study were below this threshold both before and after the intervention suggesting that they were performing a high-intensity exercise throughout the intervention.

Yoshitake et al. (2011) have shown that body-weight-based squat exercise increased KET/BM by 15.0% (2.18 ± 0.63 to 2.42 ± 0.58 Nm/kg) in healthy middle-aged and older women. In the current study, the gain in KET/BM was lower (10.9%) than the study of Yoshitake et al. (2011). A plausible reason for that is the frequency of exercise in the current study was only twice a week while the study of Yoshitake et al. (2011) utilized a frequency of at least six days per week. Although Nakamura et al. (2007) reported that an exercise intervention of only twice per week was not sufficient to induce significant improvements, participants in the current

study did improve functional fitness significantly. It remains to be determined if performing squat exercises in greater volume (e.g., more sets, greater training frequency, longer training duration) would result in additional increases in the outcomes assessed in this study. Further research is needed to clarify this point.

According to Yoshitake et al. (2011), the effect of training on lower muscle strength using body mass depends on the baseline value before intervention. This is because the level of muscle activity in the quadriceps during the squat movement is inversely correlated with KET/BM (Takai et al., 2008; Fujita et al., 2011), so the lower the KET/BM, the higher the intensity of exercise becomes. The results of the current study did not show a significant correlation between KET/BM before the intervention and the relative changes after the intervention. One explanation for this may be that the number of subjects in this study was smaller than that in the previous study by Yoshitake et al. (2011) and the KET/BW values were within a narrower range (0.73 to 1.89 Nm/kg)

than the studies of Takai et al. (2008) and Yoshitake et al. (2011).

Squat and sit-to-stand movements are accompanied by forward and backward weight shift in the sagittal plane (Schenkmen et al., 1990). Therefore, we expected that if squat training were to have an effect on balance that such improvements would appear in the forward and backward directions. Although strength improved, there were no appreciable changes in DB nor in SB, except SV standing on a firm surface with the eyes open improved by 26.2%. In many cases, falls are caused by a loss of balance (Nickens, 1985; Tinetti and Speechley, 1989). During both static and dynamic balance, posture is controlled by the detection of disturbances to the center of gravity and the initiation of appropriate responses to return the body to a stable position. This is a complex process controlled to a large extent by the visual, somatosensory, and vestibular systems. In addition, the muscular system contributes to balance control since all body movements are produced via contraction of skeletal muscles. With increasing age, there is a decrease in sensory function (Wolfson et al., 1992; Era et al., 2006) and a decrease in muscle strength (Porter et al., 1995). Slobounov et al. (1998) measured postural sway in older adults aged 67 to 92 years and found that postural sway, with eyes open and closed, increased with age, but was affected to a much greater extent when visual cues were removed. Hasan et al. (1990) investigated changes in postural sway in women over the age of 65 during eyes open double stance, eyes open single stance, eyes closed double stance, and eyes closed single stance. The velocity of sway increased when the visual cues were removed and when the feet were positioned to reduce the size of the base. Therefore, the effect of vision on postural sway may become increasingly important with age. Furthermore, a reduced base of support (e.g., when the feet are in the semi-tandem, tandem, or unilateral positions as occurs during walking) may increase the risk for suffering a fall, especially in dimly illuminated conditions that compromise visual sensation. Although Takeshima et al. (2013) have shown that an age-related decline exists for both SB and DB, we have also shown that customized balance training can improve dynamic balance (Narita et al., 2015), so it is possible that the inclusion of some balance training activities with the squat exercises used in the current study may im-

prove muscle strength, muscle thickness, and postural balance in frail older adults which could contribute to the prevention of falls. Many balance exercises can be performed with only the use of a chair and could easily be performed in conjunction with body-weight squats exercises without requiring additional space or equipment.

A limitation of this study is the lack of a control group. Although this is appropriate and acceptable for a quasi-experimental design, a stronger defense of the intervention would be made with a controlled, randomized approach.

In conclusion, group-based body-weight squat exercise performed twice weekly for 12 weeks does improve muscle strength and muscle thickness in physically frail older adults. This program is effective, simple and inexpensive, making it suitable for this population.

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