Weekly exercise programme with foot exercises to improve physical function in community-dwelling pre-frail older adults

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ABSTRACT

Background. To investigate the effect of an exercise programme incorporating foot exercises on improving physical function among community-dwelling pre-frail older adults.

Method. 13 men and 59 women (mean age, 78.5 years) with pre-frail status joined the exercise programme (a 90-minute session once a week for 3 months). The main exercises comprise strengthening of the muscles in the arms, trunk, hips, and knees, as well as 10 minutes of foot exercises that comprise toe grasp training or ankle joint stretches/strengthening. Subjective physical function was measured using the motor ability domain of the frailty checklist. Objective physical function was assessed by a single nurse using the toe grip strength (TGS), five-repetition sit-to-stand test (5STS), one-leg standing duration with eyes open (OLS), 5-m walk test (5WT), and timed up-and-go test (TUGT).

Results. In terms of subjective physical function, there was a significant improvement in leg muscle strength, walking endurance, and fear of falling. In terms of objective physical function, the mean TGS increased from 2.6 kg to 2.9 kg for the left side ($p=0.005$) and from 2.7 kg to 3.0 kg for the right side ($p=0.004$). Time taken for 5STS decreased from 9.7 s to 9.1 s ($p=0.037$), and time taken for 5WT decreased from 4.5 s to 4.2 s ($p=0.003$). However, time taken for OLS and TUGT (balance ability) did not improve significantly.

Conclusion. Exercise programme incorporating foot exercises can improve walking ability and leg muscle strength in community-dwelling pre-frail older adults. Nonetheless, the fall risk remains if balance ability is not improved.

Key words: Accidental falls; Frail elderly; Muscle strength; Toes

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INTRODUCTION

According to a 2013 report from the Japanese Ministry of Health, Labor, and Welfare, 'falls and fractures' and 'joint disease' combined were the leading cause of long-term care among older adults in Japan, accounting for 22.7% of all causes.¹ Falls, fractures, and joint disease can cause locomotive

syndrome,² and prevention is a priority for older adults.^{3–6} Frail older adults are at high risk of falls and joint disease owing to muscle weakness and poor balance.^{7,8} Frailty can be categorised as non-frailty, pre-frailty, and frailty.^{7,9} Pre-frailty is defined as the presence of at least one of the following five indicators: unintentional weight loss, weakness, exhaustion, slowness, and low physical activity;⁹

early intervention is important at this stage.^{7,9} In 2006, the Japanese Ministry of Health, Labor, and Welfare launched a 3-month exercise programme for community-dwelling pre-frail older adults to prevent falls by improving physical function.¹⁰ The programme was found to save long-term care costs but was not effective in improving self-reported physical function (measured by the frailty checklist). However, physical measurements were not assessed, and the frailty checklist alone may not accurately reflect the physical ability.¹¹

Foot and ankle functions, particularly toe grip strength (TGS), are considered the most important physical function associated with the risk of falls among older adults.^{12,13} TGS and plantar tactile sensation are closely associated with balance ability among older adults.¹⁴ Cutaneous mechanoreceptors are located in the plantar fascia and the muscular, articular, and periarticular structures of the feet.^{15,16} Cutaneous afferent inputs from the sole of the foot provide information to control posture and locomotion.¹⁷ Toe elevation angle is an index of dynamic balance ability for pre-frail older adults.¹⁸ However, these findings are derived from cross-sectional studies, and the effect of improving TGS remains unknown. Characteristics of older adults are heterogeneous.¹⁹ Thus, this study aimed to investigate the effect of an exercise programme incorporating foot exercises on improving physical function among community-dwelling pre-frail older adults.

METHODS

This pre- and post-intervention study was conducted between May 2013 and January 2016 and was approved by the Ethics Committee of Nagasaki University Graduate School of Biomedical Sciences (reference: 17081085). Written informed consent was obtained from each participant before the intervention.

The frailty checklist was mailed to all 1346 community-living older adults aged ≥ 65 years in the area. Of these, 958 (71.2%) returned the completed frailty checklist and 144 (15.0%) of them were categorised as pre-frail. The frailty checklist comprises 25 questions relating to lifestyle ($n=5$), motor ability ($n=5$), nutrition ($n=2$), oral function ($n=3$), homeboundness ($n=2$), forgetfulness ($n=3$),

and emotions ($n=5$). Pre-frailty is defined as having impaired motor or oral function, malnutrition, impaired lifestyle, or a total score of 10 excluding the domain for emotions.¹⁰

The 144 pre-frail older adults were invited to an interview with a public health nurse to confirm their eligibility. Their characteristics and medical history (bone and joint disease) were recorded. Of them, 72 (50.0%) agreed to participate in a 3-month exercise programme. Of these, 13 dropped out owing to disease, declining motivation, travel, or family obligations. None was due to an adverse event (eg, a fall or experiencing pain). Finally, 59 participants (48 women and 11 men) completed the exercise programme.

The exercise programme was conducted one session per week at a daycare centre in a suburban area in southwest Japan. Each session lasts 90 minutes and comprises a medical checkup (10 minutes), warm-up (20 minutes), main exercises (40 minutes, including a 10-minute tea break), cool-down (10 minutes), and lecture (10 minutes). The warm-up and cool-down comprise mild stretching (shoulder rotation, waist rotation, stretching the arms upward, and lateral bending of the arms, hip flexors and hip extensors, and heel raises). The main exercises comprise strengthening of the muscles in the arms, trunk, hips, and knees, as well as 10 minutes of foot exercises that comprise toe grasp training or ankle joint stretches/strengthening (**TABLE 1**) alternately each session. The intensity of the main exercises increases progressively over 3 months. Each session was attended by a median of 10 (range, 5 to 15) participants and supervised by two nurses; the median attendance rate was 12 (range, 9 to 12) sessions.

Subjective physical function was measured using the motor ability domain of the frailty checklist.¹⁰ The domain comprises five questions, with yes scored 0 and no scored 1: (1) Do you climb stairs without holding onto a handrail or the wall? (2) Do you get up from a chair without grabbing something? (3) Can you keep walking for over 15 min? (4) Do you have a fear of falling? and (5) Have you fallen within the last year?. For (5), a fall is defined as “unintentionally coming to rest on the ground or at some other lower level, not as a result of a major intrinsic event (eg, stroke) or overwhelming hazard”.²⁰ Falls history

TABLE 1
Description of the foot exercises

Exercise	Instructions	Repetitions
Toe grasp training		
Towel gathering	Sit in a chair and pull a towel with your toes little by little while keeping the heels on the floor.	5
Rolling a rubber ball	Sit in a chair and roll a rubber ball beneath your bare foot	50 per foot
Grasping a rubber ball	Sit in a chair and pick up a rubber ball with your toes and placing it in a box	10 per foot
Ankle joint stretches		
Ankle range of motion	Sit in a chair and place one ankle on top of the other knee and rotate the foot clockwise and then counter-clockwise	10 in each direction per foot
Ankle joint strengthening		
Ankle plantarflexion strength	Sit in a chair and raise both legs and point both feet as much as you can for 10 s	10
Ankle dorsiflexion strength	Sit in a chair and raise both legs and flex both feet as much as you can for 10 s	10

was collected at baseline and at 3 months post-intervention.

Objective physical function was assessed by a single nurse using the TGS, five-repetition sit-to-stand test (5STS), one-leg standing duration with eyes open (OLS), 5-m walk test (5WT), and timed up-and-go test (TUGT).²¹ The TGS of each side was measured using a dynamometer (Nisshin Industry, Saitama, Japan), with participants sitting and the knee bent at 90°. OLS of each side was measured with 60 s as the upper limit. All tests were conducted twice, and the better value was recorded.

Statistical analyses were performed using SPSS (Windows version 23; IBM Corp, Armonk [NY], US). Results at baseline and 3 months were compared. The McNemar test was used to compare score at baseline and post-intervention for each question of the motor ability domain. The paired t-test was performed to compare the objective measurements at baseline and post-intervention.

RESULTS

13 men and 59 women (mean age, 78.5 years) joined the exercise programme (**TABLE 2**). The most common joint disease occurred at the knee (54.2%), followed by the lumbar spine (45.8%). At baseline, 23 (31.9%) participants had a history of falls in the previous 12 months. In terms of subjective physical function, there was significant improvement in leg muscle strength (questions 1 and 2) [$p=0.057$ and $p=0.003$, respectively], walking endurance (question

TABLE 2
Characteristics of the participants at baseline (n=72)*

Sex	
Men	13 (18.1)
Women	59 (81.9)
Age, y	78.5±5.6
Body mass index, kg/m ²	23.1±3.2
Falls in the previous 12 months	23 (31.9)
Joint disease	
Lumbar spine	
Present	33 (45.8)
Absent	39 (54.2)
Hip joint	
Present	3 (4.2)
Absent	69 (95.8)
Knee joint	
Present	39 (54.2)
Absent	33 (45.8)
Ankle joint	
Present	8 (11.1)
Absent	64 (88.9)

* Data are presented as mean ± standard deviation or no. (%) of participants

3) [$p=0.031$], and fear of falling (question 4) [$p<0.001$] (**TABLE 3**).

In terms of objective physical function, the mean TGS increased from 2.6 kg to 2.9 kg for the left side ($p=0.005$) and from 2.7 kg to 3.0 kg for the right side ($p=0.004$). Time taken for 5STS decreased from 9.7 s to 9.1 s ($p=0.037$), and time taken for 5WT decreased

TABLE 3
Subjective and objective physical function of participants at baseline and post-intervention (n=59)

Physical function	Baseline*	Post-intervention*	p Value
Motor ability domain of the frailty checklist			
Do you climb stairs without holding onto a handrail or the wall? (No)	51 (86.4)	43 (72.9)	0.057
Do you get up from a chair without grabbing something? (No)	40 (67.8)	25 (42.4)	0.003
Can you keep walking for over 15 minutes? (No)	17 (28.8)	7 (11.9)	0.031
Do you have a fear of falling? (Yes)	56 (94.9)	43 (72.9)	<0.001
Have you fallen within the last year? (Yes)	19 (32.2)	12 (20.3)	0.118
Physical measurements			
Right toe grip strength, kg	2.7±1.1	3.0±1.2	0.005
Left toe grip strength, kg	2.6±1.1	2.9±1.1	0.004
Five-repetition sit-to-stand test, sec	9.7±3.0	9.1±2.3	0.037
One-leg standing, sec	16.4±20.8	16.7±25.2	0.945
5-m walk test, sec	4.5±1.1	4.2±1.1	0.003
Timed up-and-go test, sec	8.9±3.8	8.3±1.8	0.177

* Data are presented as mean ± standard or no. (%) of participants

from 4.5 s to 4.2 s ($p=0.003$) [TABLE 3]. However, time taken for OLS and TUGT (balance ability) did not improve significantly.

DISCUSSION

Our findings are in agreement with those suggesting that full-range toe flexion exercises may strengthen TGS.²² Toe-grasp training was combined with tactile stimulation through grasping a rubber ball and rolling the ball beneath the bare feet. Foot exercises that include stimulation of tactile sensation are useful for older adults to enhance physical performance.^{16,23} Our exercise programme with foot exercises significantly improved walking ability and leg muscle strength among pre-frail older adults. The toe flexor muscles are crucial in the propulsive force in the late stance phase of the gait cycle.²⁴ In a cross-sectional survey of 227 Japanese aged 20 to 79 years, older women aged ≥ 60 years are predisposed to weak TGS.²⁵ Strengthening TGS can improve walking ability, whereas muscle stretches and strengthening of the whole body including arm, trunk, hip, knee, and foot can improve muscle strength.^{8,26,27}

However, static and dynamic balance ability was not significantly improved. Improved TGS was not positively correlated with improved OLS or TUGT (balance ability). TGS represents the muscle strength of the foot sole and the sural region (such as the flexor hallucis longus muscle and flexor digitorum

longus muscle) but not the muscle strength of the femoral region (such as the quadriceps femoris muscle).²⁴ Balance ability requires not only TGS but also comprehensive muscle strength of the lower limbs and hips (ie, quadriceps, iliopsoas, and gluteus medius muscles). Hence, improved TGS did not contribute to improved balance ability. Nonetheless, balance ability is associated with posture sway control, suggesting that ankle strength is important for fall prevention among older adults.^{14,28,29} Therefore, stretching and strengthening of the toe/ankle joint may improve balance. An exercise programme incorporating Tai Chi exercises was reported to improve balance ability but not the leg muscle strength among Japanese pre-frail older adults.³⁰ A personalised compensation strategy for improving both balance and muscle strength is needed to prevent falls.¹⁹ Further research is needed to develop an optimal exercise programme.

Limitations of this study include the small sample size, lack of a control group, and potential selection bias. Therefore, our findings cannot be generalised to other community-dwelling pre-frail older adults and should be interpreted with caution. Moreover, confounders such as hallux valgus and joint pain might affect TGS and other physical functions.

CONCLUSIONS

Exercise programme incorporating foot exercises

can improve walking ability and leg muscle strength in community-dwelling pre-frail older adults. Nonetheless, the fall risk remains if balance ability is not improved.

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DECLARATION

The authors have no conflicts of interest to disclose.

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