ORIGINAL

Effects of exercise intervention according to functional decline risk before and after the study among community-dwelling older adults

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Abstract : Introduction : This study aimed to clarify the effects of exercise interventions on the risk of functional decline. Methods : This study included community-dwelling older adults who volunteered to participate in physical fitness measurement sessions and remote exercise classes. The participants were stratified into high-risk (HR) and low-risk (LR) groups based on the cutoff value (16/17 points) of the risk assessment scale for incident functional disability. Body composition and physical function were measured before the exercise intervention, and changes were re-measured 2–3 months after the exercise. Results : The analysis included 65 participants with complete data. Twenty-five had HR, and 40 had LR. In the HR group, significant decreases were observed in leg muscle score, phase angle of the whole body and lower limbs, gait speed, and single-leg stance. After exercise, handgrip strength and gait speed improved significantly in both the HR ($p<0.001$, $p<0.001$) and LR ($p=0.002$, $p<0.001$) groups. Fat mass and body fat percentage also increased significantly in the HR ($p=0.022$, $p=0.017$) and LR ($p=0.001$, $p<0.001$) groups. Conclusion : Exercise intervention improves physical function regardless of the risk of functional decline. However, certain challenges in maintaining body composition have been observed, suggesting the need for nutritional interventions. J. Med. Invest. 73 : 143-152, February, 2026

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INTRODUCTION

Japan has a larger population of older adults than other countries (1). Accordingly, Japan's long-term care insurance system was developed in 2000, considering future demographic trends and national budgets related to the aging population and the associated medical demands (2). However, 11 years after the establishment of the long-term care insurance system, the cost of long-term care benefits has increased 2.3-fold, and the number of long-term care insurance users is expected to increase in the future (1, 3). An increase in long-term care benefits is critical for the future (3). Preventive interventions for older populations are critical for avoiding the need for long-term care and assistance. Factors associated with deteriorating physical function affect state-incident long-term care and support (4). Therefore, exercise interventions are critical because enhancing physical function in older adults can prevent the need for long-term care and assistance (4).

Regarding the effects of exercise interventions in community-dwelling older adults, improvements in muscle strength and physical function have been documented in those with sarcopenia (5, 6), indicating that exercise interventions can reverse sarcopenic states. Furthermore, improvements in muscle quality and physical performance (7) ; reduction in fat mass ; increased skeletal muscle mass and free fat mass (8) ; maintenance of functionality, bone density, and serum cholesterol levels ; and improvements in muscle strength (9) have been observed in healthy community-dwelling older adults, leading to the maintenance and improvement of body composition and physical performance. Previous studies have shown that exercise programs benefit community-dwelling older adults.

However, to the best of our knowledge, no study has demonstrated the effectiveness of exercise interventions in a mixed population of older adult patients with varying levels of functional decline risk, such as those with sarcopenia, or in healthy older adults. Since 2015, the main strategy for community-based long-term care prevention in Japan has shifted from a high-risk (HR) strategy (10), in which older HR individuals are selected for preventive intervention, to a community-based population strategy (11), in which preventive interventions are provided to the entire population, regardless of risk (2). Consequently, regions where long-term care prevention initiatives are implemented are expected to include older adults with varying risks of functional decline. To validate the effectiveness of a long-term care prevention program based on a community-based population strategy, it is necessary to analyze the variations in the effects of exercise interventions on various target groups.

In this study, we used the risk assessment scale for incident functional disability (RFD) (12), a predictive measure of the

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likelihood of being certified as requiring assistance or care, to divide community-dwelling older adults into two groups, HR and low-risk (LR), based on their risk of being certified as requiring long-term care and support. This study aimed to clarify the effects of exercise interventions according to different levels of risk of functional decline.

MATERIALS AND METHODS

Participants

The participants were 86 older adults (19 males and 67 females ; age : 64–94 years) who volunteered to participate in physical fitness measurement sessions and remote exercise classes that were publicly recruited by the city. We explained in writing to all participants the benefits and risks of the exercise intervention and the medical response in the event of an accident and obtained written informed consent.

This study was approved by the Medical Ethics Review Board of Fukui University (approval no. 20220048) and was conducted in compliance with the Declaration of Helsinki (revised in Fortaleza in 2013) and the Ethical Guidelines for Life Science and Medical Research Involving Human Subjects (Notification No. 1 of the Ministry of Education, Culture, Sports, Science and Technology ; Ministry of Health, Labour and Welfare ; and Ministry of Economy, Trade and Industry on March 23, 2021).

Exercise interventions

Exercise classes were conducted as part of a general care prevention program in each city (Katsuyama City, July–October 2022 ; Sakai City, October–December 2022). These classes were held 11, 12, and 14 times at Venues A, B, and C, respectively. The exercise interventions used in this study were similar to those previously reported (13). Briefly, this program consisted of one-hour sessions once a week and was conducted as a real-time remote exercise using Zoom (Zoom Video Communications, Inc., USA). Participants gathered at a local community center where the Zoom broadcast was set up for viewing and received exercise guidance from a trainer (health fitness instructor) from a remote location via a screen monitor. The content included stretching while sitting or standing, dual-task training (combining physical and cognitive exercise), muscle training, and coordinated movement and was generally a low-intensity exercise of less than three metabolic equivalents of task (METs). For further details, please refer to a previous study (13). The participation rate (percentage) of participants during the exercise classes was calculated by dividing the number of times they participated by the number of times the classes were held. In the exercise class, the participants were also instructed on self-training in some of the exercises performed in the class and encouraged to perform them at home ; participation in home exercises was voluntary, and the frequency of self-training by the participants was not recorded. A follow-up examination was performed using the same survey items as those used in the baseline evaluation to assess improvements after the exercise intervention.

Data collection

Before the exercise session, a baseline assessment was performed after all participants provided written informed consent, and reassessments were conducted after the exercise intervention.

Body composition (height, weight, body mass index [BMI], skeletal muscle mass index [SMI], muscle mass [MM], leg muscle score, estimated bone mass, basal metabolic rate [BMR], fat mass [FM], body fat percentage, visceral fat level, whole-body muscle score, and phase angle [PA]) and physical function (handgrip strength [HG], gait speed [GS], chair stand test [CS], and single-leg stance [SLS]) were evaluated. The measurement items were comprehensively selected to include muscle mass/quality, muscle strength, and physical function, which are related to sarcopenia and risk factors for requiring assistance and care (14-16). Additionally, bone mass and fat indices, which have been suggested to be related to MM and exercise function, were incorporated to provide multifaceted measurements (17, 18). Functional decline risk was assessed using the RFD (12), an indicator of the likelihood of certification requiring assistance or care.

Anthropometry

A height meter (seca228 ; AS ONE Co., Ltd., Osaka, Japan) was used to measure the height. A multi-frequency eight-electrode body composition analyzer (MC-780A-N and MC-780A ; Tanita Co., Ltd., Tokyo, Japan) was used to measure other body compositions. The SMI was calculated as the sum of the limb skeletal MM divided by the square of the participant's height. The leg muscle score is Tanita's proprietary measurement of lower limb MM as a percentage of body weight based on data accumulated by the Tanita Institute of Weight Science and is converted into a score. The criteria are 90–150 points, "good" ; 80–89 points, "slightly low" ; and 50–79 points, "low" (19). The whole-body muscle score was calculated and classified according to MM in relation to height. Higher values indicate more MM for height (low, –4 to –2 ; average, –1 to 1 ; high, +2 to +4) (19). PA is an index calculated directly from measured values using bioelectrical impedance analysis (BIA) without any estimation equation and reflects the cellular physiological function level (20, 21). Muscle quality was assessed using BIA-derived PA measurements (14). PA represents structural perfection. The higher the value, the better the muscle composition (i.e., muscle quality) ; the lower the value, the poorer the muscle composition (22, 23).

Physical performances

A Smedley-type handgrip dynamometer (TTM ; Tsutsumi Seisakusyo Co., Ltd., Tokyo, Japan) was used to measure the left and right HG twice, and the maximum values were identified for analysis. To calculate the GS (m/s), we used a stopwatch to measure the time (s) required to walk 5 m at a brisk pace and used the minimum value of the two measurements for analysis. A 3-m interval was set aside before and after the 5-m measuring interval to accommodate acceleration and deceleration at the start and end of walking, with a walking interval of 11 m. CS was repeated five times with the participant sitting in a chair with the arms crossed in front of the chest. The participant then stood with the trunk, both knee joints were fully extended, and returned swiftly to their sitting posture. The time required to complete the fifth sitting session was also recorded. The time required to maintain the open-eyed SLS was measured twice using a stopwatch, with a maximum time of 120 s. For the analysis, the maximum value of the two measurements was used.

Statistical analysis

This study aimed to verify the effects of exercise intervention according to functional decline risk, as measured by the RFD. In analyzing the data, participants who had already been certified as requiring long-term care and support at the time of the survey were excluded. In addition, participants who were difficult to follow up with, such as those who discontinued participation in exercise classes or did not participate in physical fitness measurement sessions after the exercise intervention, were also excluded. Based on the RFD cutoff value (16/17 points), participants were stratified into HR (≥17 points) and LR (<17 points) groups, and the intervention effects were independently examined within each group. Older adult individuals at risk of functional decline exhibit declines in body composition and physical function (14, 24, 25) ; therefore, baseline characteristics were assumed to differ between the HR and LR groups in this study. Therefore, baseline differences may influence the evaluation of the effects of the exercise intervention. Rather than comparing the interaction between groups and time to evaluate the intervention effects, we used a stratification analysis to examine each group individually.

Baseline characteristics between groups were compared using the chi-square test for sex, a categorical variable, and the Mann–Whitney U test for age, body composition, and physical function, which are continuous variables. In addition, the distribution of venues attended was compared between the groups using the chi-square test, and the number of sessions attended and participation rates were compared using the Mann–Whitney U test. The Wilcoxon signed-rank test was used to compare changes in body composition and physical function between the HR and LR groups before and after the exercise intervention, and the r-value was computed as the effect size (ES) (26). Furthermore, the Hodges–Lehmann (H–L) median difference with its 95% confidence interval was calculated (27). As a sensitivity analysis, multivariate linear regression was conducted using post-intervention values of body composition or physical function variables that showed significant pre–post differences as the dependent variables and baseline values and the number of exercise class participations as the independent variables to adjust for the influence of participation frequency. This analysis examined the robustness of the intervention effects when participation frequency was included as a covariate (28). Statistical data were analyzed using EZR version 1.68 (29). Statistical significance was set at $p < 0.05$.

RESULTS

Of the 86 participants, three had been certified as incident long-term care and support at the time of the survey, one had missing body composition data, one had difficulty with physical function measurement, and 16 were difficult to follow up with before and after the exercise intervention, resulting in 65 participants with complete data for analysis (Figure 1). Among the 65 participants, 17 (26.2%) were male and 48 (73.8%) were female, with an average age of 74.8±6.2 years. In the RFD group, 25 (38.5%) patients were in the HR group and 40 (61.5%) were in the LR group. Details of the basic attributes, including each measurement item, are presented in Table 1. The number of participants at each venue was 21 (32.3%) at Venue A, 17 (26.2%) at Venue B, and 27 (41.5%) at Venue C. The mean number of sessions attended was 10.4±2.1, and the mean attendance rate was 83.3±16.3%.

Characteristics of participants

Sex differences between the HR (9 males and 16 females) and LR (8 males and 32 females) groups were not statistically significant. Age was significantly higher in the HR group than in the LR group ($p<0.001$). Regarding participation in exercise classes, a significant difference was observed between the two groups in the distribution of the venues attended ($p=0.001$), but no significant differences were found between the two groups in the number of sessions attended or the participation rate. At baseline, the HR group had significantly lower leg muscle scores, PA (whole body and lower limbs), GS, and SLS than the LR group ($p<0.001$, $p=0.009$, $p=0.003$, $p=0.005$, and $p=0.025$, respectively ; Table 2).

Comparison before and after the exercise intervention

The HR group showed significantly improved height, PA (whole body), HG, and GS after exercise [$p=0.026$, ES=0.45, Hodges–Lehmann estimate (95% CI) : 0.25 (0.05 to 0.40) ; $p=0.038$,

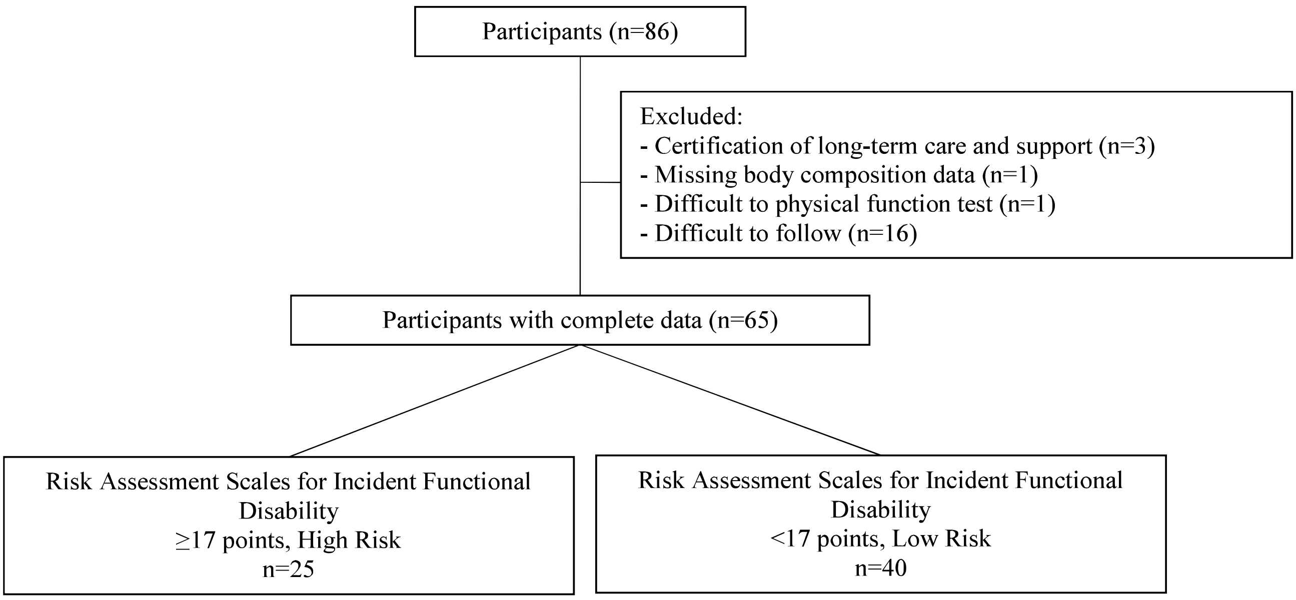

Figure 1. Flowchart of inclusion and exclusion criteria of participants

ES=0.42, 0.30 (0.00 to 0.65) ; p<0.001, ES=0.76, 2.60 (1.55 to 3.60) ; p<0.001, ES=0.72, 0.35 (0.20 to 0.50), respectively]. In addition, the FM and body fat percentages significantly increased [p=0.022, ES=0.47, Hodges–Lehmann estimate (95% CI) : 0.65 (0.15 to 1.20) ; p=0.017, ES=0.48, 1.10 (0.25 to 1.85), respectively]. In the sensitivity analysis, no significant associations were found between the number of sessions attended and any of the post-intervention measures of body composition or physical function (Table 3).

The LR group had significantly improved HG, GS, and CS after exercise [p=0.002, ES=0.48, Hodges–Lehmann estimate (95% CI) : 1.70 (0.70 to 2.45) ; p<0.001, ES=0.64, 0.25 (0.15 to 0.35) ; p<0.001, ES=–0.62, –1.10 (–1.60 to –0.65), respectively]. In addition, SMI, MM, estimated bone mass, BMR, and whole-body muscle score decreased significantly [p<0.001, ES=–0.64, Hodges–Lehmann estimate (95% CI) : –0.20 (–0.25 to –0.10) ; p<0.001, ES=–0.59, –0.55 (–0.80 to –0.30) ; p=0.003, ES : –0.47, –0.10 (–0.15 to –0.10) ; p<0.001, ES=–0.56, –13.00 (–19.50 to –6.50) ; p=0.003, ES=–0.47, –1.00 (–1.00 to –1.00), respectively], and FM and body fat percentage increased significantly [p=0.001, ES=0.51, Hodges–Lehmann estimate (95% CI) : 0.65 (0.25 to 0.95) ; p<0.001, ES=0.60, 1.25 (0.70 to 1.80), respectively]. Sensitivity analysis revealed significant associations between participation frequency and post-intervention SMI, BMR, and HG (β=–0.03, 95% CI : –0.06 to –0.00, p=0.044 ; β=–2.99, 95% CI : –5.56 to –0.42, p=0.024 ; β=–0.49, 95% CI : –0.85 to –0.12, p=0.010, respectively ; Table 4).

Table 1. Basic participant characteristics

Variable		Unit	Overall	Male	Female	Reference value
			n=65	n=17	n=48	
Sex	Male	n (%)	17 (26.2)	17 (100.0)	0 (0.0)	—
	Female	n (%)	48 (73.8)	0 (0.0)	48 (100.0)	—
Age		years	74.8 ± 6.2	76.7 ± 4.6	74.2 ± 6.7	—
Exercise class	Participants at venue A	n (%)	21 (32.3)	7 (41.2)	14 (29.2)	—
	Participants at venue B	n (%)	17 (26.2)	5 (29.4)	12 (25.0)	—
	Participants at venue C	n (%)	27 (41.5)	5 (29.4)	22 (45.8)	—
	Number of times participating	times	10.4 ± 2.1	10.2 ± 2.3	10.4 ± 2.0	—
	participation rate	%	83.3 ± 16.3	84.0 ± 18.3	83.1 ± 15.7	—
Body composition						
Height		cm	155.1 ± 7.4	162.6 ± 5.9	152.4 ± 5.9	—
Weight		kg	54.3 ± 8.9	62.1 ± 7.1	51.6 ± 7.9	—
BMI		%	22.6 ± 3.3	23.5 ± 2.8	22.2 ± 3.4	18.5–25*
SMI		kg/m^2	6.8 ± 0.8	7.7 ± 0.7	6.5 ± 0.6	Males, <7.0 ; Females, <5.7†
MM		kg	36.9 ± 6.3	45.6 ± 3.9	33.8 ± 3.4	—
Leg muscle score		point	89.7 ± 9.3	85.4 ± 7.5	91.3 ± 9.5	90–150*
Estimated bone mass		kg	2.1 ± 0.4	2.5 ± 0.2	2.0 ± 0.3	—
BMR		kcal	1091.9 ± 162.0	1291.6 ± 118.9	1021.1 ± 106.7	Males : 50–69 y/o, 1400 ; 70 y/o–, 1290 ; Females : 50–69 y/o, 1100 ; 70 y/o–, 1020*
FM		kg	15.3 ± 5.8	13.9 ± 4.9	15.8 ± 6.1	—
Body fat percentage		%	27.8 ± 7.8	22.0 ± 6.0	29.9 ± 7.3	Males, 14–24 ; Females, 23–36*
Visceral fat level			7.2 ± 3.7	11.4 ± 3.0	5.8 ± 2.7	≤9.5*
Whole-body muscle score			–0.4 ± 1.2	–0.4 ± 1.2	–0.4 ± 1.2	–1–1*
PA	Whole body	°	4.7 ± 0.6	5.1 ± 0.5	4.6 ± 0.5	—
	Both arms	°	5.2 ± 0.6	5.6 ± 0.5	5.1 ± 0.5	—
	Both lower limbs	°	4.3 ± 0.7	4.6 ± 0.6	4.2 ± 0.7	—
Physical function						
HG		kg	27.8 ± 6.7	34.4 ± 5.4	25.5 ± 5.4	Males, <28 ; Females, <18†
GS		m/s	2.2 ± 0.4	2.3 ± 0.5	2.2 ± 0.4	<1.0†
CS		s	7.6 ± 2.0	7.1 ± 2.0	7.8 ± 2.0	≥12†
SLS		s	61.9 ± 48.4	49.9 ± 38.4	66.2 ± 51.2	65–69 y/o, 40.8±20.7 ; 70–74 y/o, 32.5±21.6 ; 75–79 y/o, 25.5±19.9 ; 80 y/o–, 16.2±17.9‡
RFD						
Total score		point	14.1 ± 7.4	15.7 ± 6.2	13.5 ± 7.7	—
High-risk patients	RFD score ≥17	n (%)	25 (38.5)	9 (52.9)	16 (33.3)	—
Low-risk patients	RFD score <17	n (%)	40 (61.5)	8 (47.1)	32 (66.7)	—

BMI, body mass index ; SMI, skeletal muscle mass index ; MM, muscle mass ; BMR, basal metabolic rate ; FM, fat mass ; PA, phase angle ; HG, handgrip strength ; GS, gait speed ; CS, chair stand test ; SLS, single-leg stance ; RFD, risk assessment scale for incident functional disability. *Normal range (19). †Cutoff value for sarcopenia diagnosis (29). ‡Reference values by age group (4).

Table 2. Comparison of basic participant characteristics and exercise class participation between the two groups

Variable		Unit	HR n=25	LR n=40	p-value
Sex	Male	n (%)	9 (36.0)	8 (20.0)	0.25
	Female	n (%)	16 (64.0)	32 (80.0)	
Age		year	81.0 ± 4.0	71.0 ± 3.8	< 0.001*
Exercise class	Participants at venue A	n (%)	14 (56.0)	7 (17.5)	0.001*
	Participants at venue B	n (%)	7 (28.0)	10 (25.0)	
	Participants at venue C	n (%)	4 (16.0)	23 (57.5)	
	Number of times participating	times	10.2 ± 1.8	10.5 ± 2.3	0.45
	participation rate	%	87.4 ± 14.5	80.8 ± 17.0	0.145
Body composition					
Height		cm	153.8 ± 8.2	155.9 ± 6.8	0.29
Weight		kg	53.9 ± 9.5	54.6 ± 8.7	0.75
BMI		%	22.7 ± 3.4	22.5 ± 3.2	0.78
SMI		kg/m^2	6.6 ± 0.7	7.0 ± 0.8	0.099
MM		kg	36.4 ± 6.5	37.2 ± 6.3	0.59
Leg muscle score		point	84.8 ± 7.8	92.8 ± 8.9	< 0.001*
Estimated bone mass		kg	2.0 ± 0.4	2.2 ± 0.3	0.158
BMR		kcal	1065.9 ± 163.8	1108.1 ± 160.8	0.31
FM		kg	15.5 ± 5.8	15.2 ± 5.9	0.86
Body fat percentage		%	28.3 ± 7.8	27.5 ± 7.8	0.70
Visceral fat level			8.2 ± 4.0	6.6 ± 3.5	0.099
Whole-body muscle score			−0.8 ± 1.2	−0.2 ± 1.2	0.069
PA	Whole body	°	4.5 ± 0.5	4.9 ± 0.6	0.009*
	Both arms	°	5.1 ± 0.5	5.3 ± 0.6	0.130
	Both lower limbs	°	4.0 ± 0.7	4.5 ± 0.6	0.003*
Physical function					
HG		kg	26.5 ± 6.8	28.6 ± 6.6	0.22
GS		m/s	2.0 ± 0.4	2.3 ± 0.4	0.005*
CS		s	7.8 ± 2.1	7.5 ± 1.9	0.58
SLS		s	45.0 ± 44.3	72.5 ± 48.4	0.025*

BMI, body mass index ; SMI, skeletal muscle mass index ; MM, muscle mass ; BMR, basal metabolic rate ; FM, fat mass ; PA, phase angle ; HG, handgrip strength ; GS, gait speed ; CS, chair stand test ; SLS, single-leg stance. *p-value < 0.05.

DISCUSSION

This study aimed to elucidate the effects of exercise interventions on the risk of functional decline. Using the RFD, community-dwelling older adults were classified into HR and LR groups, and a stratified analysis of the effects of the exercise intervention was performed. As a result of the exercise intervention, both groups showed improvements in physical function (HR group : HG and GS ; LR group : HG, GS, and CS), and the HR group also showed improvements in whole-body muscle quality. In contrast, both groups showed increases in FM and body fat percentage, and the LR group showed decreases in MM, SMI, whole-body muscle score, estimated bone mass, and BMR, indicating certain challenges in maintaining body composition.

A previous study demonstrated that the lower limbs show a decrease in muscular strength and quality with aging compared with the upper limbs (30), resulting in a decline in lower limb physical function (31). In this study, older adults in the HR group were older than those in the LR group and exhibited age-related declines in lower limb muscle mass/quality, as well as lower limb physical function, similar to those reported in previous studies. Therefore, the HR and LR groups in this study represent a population of community-dwelling older adults with age-related lower limb dysfunction, as reported in previous studies.

In this study, both the HR and LR groups showed improvements in HG and GS following the exercise intervention, and the LR group also showed improvements in CS. Muscle strength (HG) and physical function (GS or CS) are the gold standards for sarcopenia diagnosis (32). Sarcopenia is a risk factor for incident long-term care and support (15, 25, 32), and the improvements in muscle strength and physical function observed in this study are expected to help prevent progression to sarcopenia or long-term care dependency. Japan's long-term care prevention programs have shifted from an HR strategy targeting individuals with functional decline risk to a community-based population strategy intervening in the entire population regardless of risk status (2). This study demonstrated improvements in physical function regardless of the level of functional decline risk, supporting the

Table 3. Comparison before-and-after exercise intervention (HR, n=25)

Variable	Unit	Pre	Post	p-value	ES (r-value)	Hodges–Lehmann median difference (95%CI)	Number of times participating †		
							β	95%CI	p-value
Body composition									
Height	cm	153.8 ± 8.2	154.0 ± 8.3	0.026*	0.45	0.25 (0.05 to 0.40)	0.06	−0.03 to 0.16	0.182
Weight	kg	53.9 ± 9.5	54.3 ± 9.4	0.071	0.37	0.45 (−0.05 to 1.00)	—	—	—
BMI	%	22.7 ± 3.4	22.8 ± 3.3	0.32	0.21	0.15 (−0.10 to 0.35)	—	—	—
SMI	kg/m²	6.6 ± 0.7	6.6 ± 0.6	0.21	−0.27	−0.10 (−0.20 to 0.05)	—	—	—
MM	kg	36.4 ± 6.5	36.2 ± 6.3	0.119	−0.31	−0.30 (−0.60 to 0.10)	—	—	—
Leg muscle score	point	84.8 ± 7.8	85.2 ± 9.1	0.59	0.11	0.50 (−2.00 to 3.00)	—	—	—
Estimated bone mass	kg	2.0 ± 0.4	2.0 ± 0.4	0.62	−0.12	−0.00 (−0.10 to 0.05)	—	—	—
BMR	kcal	1065.9 ± 163.8	1062.4 ± 158.8	0.27	−0.22	−6.00 (−15.50 to 5.50)	—	—	—
FM	kg	15.5 ± 5.8	16.2 ± 5.7	0.022*	0.47	0.65 (0.15 to 1.20)	−0.05	−0.34 to 0.25	0.75
Body fat percentage	%	28.3 ± 7.8	29.3 ± 7.3	0.017*	0.48	1.10 (0.25 to 1.85)	−0.07	−0.51 to 0.37	0.74
Visceral fat level		8.2 ± 4.0	8.1 ± 4.3	0.66	−0.10	−0.00 (−1.00 to 1.00)	—	—	—
Whole-body muscle score		−0.8 ± 1.2	−0.9 ± 1.2	0.182	−0.28	−1.00 (−1.00 to −0.00)	—	—	—
PA Whole body	°	4.5 ± 0.5	4.8 ± 0.7	0.038*	0.42	0.30 (0.00 to 0.65)	0.12	−0.04 to 0.28	0.138
PA Both arms	°	5.0 ± 0.5	5.1 ± 0.6	0.55	0.12	0.05 (−0.15 to 0.25)	—	—	—
PA Both lower limbs	°	4.0 ± 0.7	4.1 ± 0.7	0.066	0.37	0.20 (−0.00 to 0.35)	—	—	—
Physical function									
HG	kg	26.5 ± 6.8	29.3 ± 6.9	<0.001*	0.76	2.60 (1.55 to 3.60)	0.11	−0.57 to 0.80	0.74
GS	m/s	2.0 ± 0.4	2.4 ± 0.4	<0.001*	0.72	0.35 (0.20 to 0.50)	0.01	−0.07 to 0.08	0.82
CS	s	7.8 ± 2.1	7.2 ± 2.3	0.097	−0.33	−0.55 (−1.12 to 0.15)	—	—	—
SLS	s	45.0 ± 44.3	44.9 ± 43.0	0.64	0.10	2.79 (−13.50 to 15.50)	—	—	—

Pre, before exercise intervention ; Post, after exercise intervention ; ES, effect size ; BMI, body mass index ; SMI, skeletal muscle mass index ; MM, muscle mass ; BMR, basal metabolic rate ; FM, fat mass ; PA, phase angle ; HG, handgrip strength ; GS, gait speed ; CS, chair stand test ; SLS, single-leg stance ; y/o, years old. The criteria for ES were a small effect size, r-value >0.10 ; a medium effect size, r-value >0.30 ; and a large effect size, r-value >0.50. The criteria for the power value : 0.8. *p-value <0.05. †Sensitivity analysis was performed using multiple linear regression with post-intervention value as the dependent variable and baseline value and number of times participating as independent variables.

Table 4. Comparison before-and-after exercise intervention (LR, n=40)

Variable	Unit	Pre	Post	p-value	ES (r-value)	Hodges–Lehmann median difference (95%CI)	Number of times participating †		
							β	95%CI	p-value
Body composition									
Height	cm	155.9 ± 6.8	156.0 ± 6.7	0.105	0.26	0.15 (−0.05 to 0.35)	—	—	—
Weight	kg	54.6 ± 8.7	54.7 ± 8.7	0.73	0.05	0.05 (−0.25 to 0.40)	—	—	—
BMI	%	22.5 ± 3.2	22.5 ± 3.1	0.77	−0.04	−0.05 (−0.20 to 0.15)	—	—	—
SMI	kg/m²	7.0 ± 0.8	6.8 ± 0.8	< 0.001*	−0.64	−0.20 (−0.25 to −0.10)	−0.03	−0.06 to −0.00	0.044*
MM	kg	37.2 ± 6.3	36.7 ± 6.0	< 0.001*	−0.59	−0.55 (−0.80 to −0.30)	−0.10	−0.20 to −0.00	0.050
Leg muscle score	point	92.8 ± 8.9	92.2 ± 8.8	0.082	−0.28	−1.50 (−2.50–0.00)	—	—	—
Estimated bone mass	kg	2.2 ± 0.3	2.1 ± 0.3	0.003*	−0.47	−0.10 (−0.15 to −0.10)	−0.00	−0.01 to 0.01	0.84
BMR	kcal	1108.1 ± 160.8	1095.2 ± 155.6	< 0.001*	−0.56	−13.00 (−19.50 to −6.50)	−2.99	−5.56 to −0.42	0.024*
FM	kg	15.2 ± 5.9	15.9 ± 5.6	0.001*	0.51	0.65 (0.25 to 0.95)	−0.10	−0.27 to 0.07	0.25
Body fat percentage	%	27.5 ± 7.8	28.7 ± 7.2	< 0.001*	0.60	1.25 (0.70 to 1.80)	−0.06	−0.32 to 0.20	0.64
Visceral fat level		6.6 ± 3.5	6.8 ± 3.6	0.103	0.26	1.00 (−0.00 to 1.00)	—	—	—
Whole-body muscle score		−0.2 ± 1.2	−0.5 ± 1.2	0.003*	−0.47	−1.00 (−1.00 to −1.00)	−0.06	−0.14 to 0.02	0.146
PA Whole body	°	4.9 ± 0.5	4.9 ± 0.6	0.70	0.04	0.00 (−0.10 to 0.15)	—	—	—
PA Both arms	°	5.2 ± 0.6	5.3 ± 0.6	0.48	0.08	0.05 (−0.10 to 0.15)	—	—	—
PA Both lower limbs	°	4.5 ± 0.6	4.5 ± 0.6	0.180	0.21	0.08 (−0.05 to 0.15)	—	—	—
Physical function									
HG	kg	28.6 ± 6.6	30.3 ± 6.4	0.002*	0.48	1.70 (0.70 to 2.45)	−0.49	−0.85 to −0.12	0.010*
GS	m/s	2.3 ± 0.4	2.6 ± 0.5	< 0.001*	0.64	0.25 (0.15 to 0.35)	−0.04	−0.08 to 0.01	0.125
CS	s	7.5 ± 1.9	6.4 ± 1.5	< 0.001*	−0.62	−1.10 (−1.60 to −0.65)	−0.12	−0.30 to 0.05	0.161
SLS	s	72.5 ± 48.4	76.1 ± 46.2	0.57	0.09	4.00 (−13.50 to 25.00)	—	—	—

Pre, before exercise intervention ; Post, after exercise intervention ; ES, effect size ; BMI, body mass index ; SMI, skeletal muscle mass index ; MM, muscle mass ; BMR, basal metabolic rate ; FM, fat mass ; PA, phase angle ; HG, handgrip strength ; GS, gait speed ; CS, chair stand test ; SLS, single-leg stance ; y/o, years old. The criteria for ES were a small effect size, r-value >0.10 ; a medium effect size, r-value >0.30 ; and a large effect size, r-value >0.50. The criteria for the power value : 0.8. *p-value <0.05. †Sensitivity analysis was performed using multiple linear regression with the post-intervention value as the dependent variable and the baseline value and number of times participating as independent variables.

necessity of a community-based population strategy that targets the entire population. Previous studies have shown that low-intensity exercise interventions are ineffective in older adults (33, 34), whereas resistance training is effective (5, 6). However, even low-intensity, low-frequency exercise regimens (1 week for 1 h per session) were successful. Exercising twice a week is difficult for older adults, and exercising twice a week is associated with refusal (35, 36), which may lead to decreased adherence to exercise interventions. The frequency of exercise in this study was low (mostly once a week), which made it easy for older adults to participate, and adherence to the exercise intervention was maintained, which may have contributed to the effectiveness of the low-intensity exercise program. Further validation of the effectiveness of the exercise intensity and frequency is required.

Although improvements in physical function were observed, an increase in body fat was noted in both groups. An increase in body fat may lead to lipid infiltration into muscles, causing muscle inflammation and potentially increasing the risk of sarcopenia (18, 37, 38). As such, an increase in body fat can contribute to age-related obesity, and excessive obesity can adversely affect overall physical condition (39, 40). On the other hand, there is the concept of the "obesity paradox," in which obesity reduces mortality risk in certain diseases or older populations (39), indicating that an increase in body fat does not always have adverse effects. Sarcopenic obesity, which combines sarcopenia with obesity, has been reported to reduce the risk of all-cause mortality compared with sarcopenia alone (40). Therefore, attention should be paid to temporal changes in body fat, regardless of the risk of functional decline, when implementing exercise interventions. Decreases in muscle and bone mass and BMR were also observed in the LR group. These results suggest that exercise intervention alone may not be sufficient to maintain the physical condition of older adults, such as those in the LR group who have a relatively good physical status. Muscle loss reduces the mechanical loading on bones and disrupts bone metabolism (17). Additionally, MM and body fat were associated with BMR (41). These findings suggest that combining exercise with nutritional interventions may be more effective in maintaining and improving body composition. Previous studies have reported increases in MM and strength (42, 43) and fat-free mass, reductions in FM (44), and improvements in bone mass (45). Therefore, to maintain good physical condition in older adults, it is essential to focus on body composition components such as body fat, muscle, and bone, and to consider comprehensive interventions combining exercise and nutrition as a future challenge.

When examining changes in body composition and physical function resulting from exercise interventions, it is necessary to consider the influence of intervention frequency as a contributing factor (46). In this study, a significant difference was observed between the two groups in the distribution of exercise class sites attended by participants, but no significant difference was found in the number of sessions attended. The results of the sensitivity analysis based on participation frequency showed that, in the HR group, participation frequency was not significantly associated with any post-intervention measures of body composition or physical function. Conversely, in the LR group, participation frequency was significantly associated with SMI, BMR, and HG after the exercise intervention. These results suggest that, while the impact of participation frequency is limited in the HR group—which has relatively lower body composition and physical function—participation frequency may influence intervention effects in the LR group, which has relatively higher body composition and physical function.

This study had some limitations. First, as in previous studies (25, 47), the participants were older individuals with high levels of physical activity and health awareness, making participant selection bias possible. Second, owing to the differences in baseline characteristics between the HR and LR groups, it was not possible to confirm interactions between-group and pre-/post-intervention factors. Additionally, the absence of a control group that did not undergo any exercise intervention underscores the necessity for a randomized controlled trial with control groups corresponding to each risk group. A more comprehensive examination of the relationship between the risk of functional decline and the effectiveness of exercise intervention is necessary. Third, this study found that the number of exercise class sessions attended was associated with some intervention effects on body composition and physical function measures. Exercise instruction for older adults requires identifying the necessary exercise frequency and volume to produce meaningful changes (46). Therefore, future research should further investigate the effects of intervention duration and frequency to determine more effective exercise intervention conditions. Fourth, because this study was limited to two regions (Katsuyama and Sakai cities) and the sample size was small, generalizability is a concern. In the future, this study should be expanded to include more regions and confirm the effects of exercise interventions based on diverse features and a greater number of participants.

We stratified community-dwelling older adults according to their functional decline risk and verified the effects of an exercise intervention. In a care prevention program based on a community-based population strategy, exercise intervention improved physical function and produced certain effects regardless of the risk level. However, exercise alone has certain challenges in maintaining body composition, suggesting that a multifaceted approach that includes nutritional interventions is essential.

DISCLOSURES

CONFLICTS OF INTEREST

HO has signed a non-disclosure agreement with Novel METS and Macnica. The authors declare no conflict of interest.

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ETHICS APPROVAL

This study was approved by the University of Fukui Medical Research Ethics Review Committee (approval number : 20220048). All researchers involved in this study complied with the Ethical Guidelines for Medical and Biological Research Involving Human Subjects (MEXT/MHLW/METI Notification No. March 1 23, 2021).

AUTHOR CONTRIBUTIONS

H.O. and O.Y. contributed significantly to the conceptualization of the study ; Y.N., H.O., Y.M., Y.N., T.O., N.K., T.T., M.K., A.M., M.I., H.H., and O.Y. contributed significantly to data acquisition ; Y.N., H.O., and O.Y. contributed significantly to data analysis and interpretation ; and Y.N., H.O., and O.Y. contributed to manuscript preparation. All authors critically reviewed and revised the manuscript and approved and submitted the final version.

REFERENCES

1. Ministry of Health, Labor and Welfare (2016) : Long-term care insurance system of Japan. Ministry of Health, Labor and Welfare. https://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ltcisj_e.pdf. Accessed May 5, 2025
2. Yamada M, Arai H : Long-term care system in Japan. Ann Geriatr Med Res 24 : 174-180, 2020
3. Ito K, Kawai H, Tsuruta H, Obuchi S : Predicting incidence of long-term care insurance certification in Japan with the Kihon Checklist for frailty screening tool : analysis of local government survey data. BMC Geriatr 21 : 22, 2021
4. Ministry of Health, Labor and Welfare (2022) : Labor and welfare. 4th ed. of preventive care manual Chapter 2 Function improvement manual of a movement container. Ministry of Health. https://www.mhlw.go.jp/content/12300000/001238862.pdf. Accessed May 5, 2025
5. Cruz-Jentoft AJ, Landi F, Schneider SM, Zúñiga C, Arai H, Boirie Y, Chen LK, Fielding RA, Martin FC, Michel JP, Sieber C, Stout JR, Studenski SA, Vellas B, Woo J, Zamboni M, Cederholm T : Prevalence of and interventions for sarcopenia in ageing adults : a systematic review. Report of the International sarcopenia Initiative (EWGSOP and IWGS). Age Ageing 43 : 748-759, 2014
6. Wang H, Huang WY, Zhao Y : Efficacy of exercise on muscle function and physical performance in older adults with sarcopenia : an updated systematic review and meta-analysis. Int J Environ Res Public Health 19 : 8212, 2022
7. Fragala MS, Fukuda DH, Stout JR, Townsend JR, Emerson NS, Boone CH, Beyer KS, Oliveira LP, Hoffman JR : Muscle quality index improves with resistance exercise training in older adults. Exp Gerontol 53 : 1-6, 2014
8. Kemmler W, von Stengel S, Engelke K, Häberle L, Mayhew JL, Kalender WA : Exercise, body composition, and functional ability : a randomized controlled trial. Am J Prev Med 38 : 279-287, 2010
9. Bunout D, Barrera G, de la Maza P, Avendaño M, Gattas V, Petermann M, Hirsch S : The impact of nutritional supplementation and resistance training on the health functioning of free-living Chilean elders : results of 18 months of follow-up. J Nutr 131 : 2441S-2446S, 2001
10. Lalonde M (1974) : A new perspective on the health of Canadians. https://www.phac-aspc.gc.ca/ph-sp/pdf/perspect-eng.pdf. Accessed May 5, 2025
11. Rose G, Kay-Tee K, Michael M : Rose's Strategy of Preventive Medicine : the complete original text, 2008. Accessed May 5, 2025. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780192630971.001.0001
12. Tsuji T, Kondo K, Kondo N, Aida J, Takagi D : Development of a risk assessment scale predicting incident functional disability among older people : Japan gerontological evaluation study. Geriatr Gerontol Int 18 : 1433-1438, 2018
13. Nakajima Y, Onishi H, Mizukami Y, Niida Y, Okamoto T, Konoshita N, Tanaka T, Matsunaga A, Kubota M, Ikawa M, Hori H, Kobayashi Y, Hayashi H, Yamamura O : Effect of remote exercise interventions on the risk of incident functional disability certification among community-dwelling older adults : before-and-after study. Asian J Occup Ther 21 : 27-36, 2025
14. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, Cooper C, Landi F, Rolland Y, Sayer AA, Schneider SM, Sieber CC, Topinkova E, Vandewoude M, Visser M, Zamboni M, Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2 (2019) : Sarcopenia : revised European consensus on definition and diagnosis. Age Ageing 48 : 16-31, 2019
15. Abe T, Kitamura A, Taniguchi Y, Amano H, Seino S, Yokoyama Y, Nishi M, Narita M, Ikeuchi T, Fujiwara Y, Shinkai S : Pathway from gait speed to incidence of disability and mortality in older adults : A mediating role of physical activity. Maturitas 123 : 32-36, 2019
16. Moriya S, Murata A, Kimura S, Inoue N, Miura H : Predictors of eligibility for long-term care funding for older people in Japan. Australas J Ageing 32 : 79-85, 2013
17. Paintin J, Cooper C, Dennison E : Osteosarcopenia. Br J Hosp Med (Lond) 79 : 253-258, 2018
18. Sternfeld B, Ngo L, Satariano WA, Tager IB : Associations of body composition with physical performance and self-reported functional limitation in elderly men and women. Am J Epidemiol 156 : 110-121, 2002
19. TANITA About Body Composition, 2024. TANITA Co., Ltd. https://tanita.zendesk.com/hc/ja/sections/115003975807. Accessed May 5, 2025
20. Lukaski HC, Kyle UG, Kondrup J : Assessment of adult malnutrition and prognosis with bioelectrical impedance analysis : phase angle and impedance ratio. Curr Opin Clin Nutr Metab Care 20 : 330-339, 2017
21. Norman K, Stobäus N, Pirlich M, Bosy-Westphal A : Bioelectrical phase angle and impedance vector analysis-clinical relevance and applicability of impedance parameters. Clin Nutr 31 : 854-861, 2012
22. Hui D, Bansal S, Morgado M, Dev R, Chisholm G, Bruera E : Phase angle for prognostication of survival in patients with advanced cancer : preliminary findings. Cancer 120 : 2207-2214, 2014
23. Kyle UG, Soundar EP, Genton L, Pichard C : Can phase angle determined by bioelectrical impedance analysis assess nutritional risk? A comparison between healthy and hospitalized subjects. Clin Nutr 31 : 875-881, 2012
24. Sawaya Y, Hirose T, Shiba T, Sato R, Yin L, Kubo A, Urano T : Decrease in the usual walking speed and body fat percentage associated with a deterioration in long-term care insurance certification levels. PeerJ 12 : e17529, 2024
25. Srithumsuk W, Kabayama M, Godai K, Klinpudtan N, Sugimoto K, Akasaka H, Takami Y, Takeya Y, Yamamoto K, Yasumoto S, Gondo Y, Arai Y, Masui Y, Ishizaki T, Shimokata H, Rakugi H, Kamide K : Association between physical function and long-term care in community-dwelling older and oldest people : the SONIC study. Environ Health Prev Med 25 : 46, 2020
26. Field A : Discovering statistics using IBM SPSS Statistics. 3rd ed. SAGE Publications, London, 2009, pp. 56-698, 2009
27. Hodges JL, Lehmann EL : Estimates of located based on rank tests. Ann Math Stat 34 : 598-611, 1963
28. Vickers AJ, Altman DG : Statistics notes : Analysing controlled trials with baseline and follow up measurements. BMJ 323 : 1123-1124, 2001
29. Kanda Y : Investigation of the freely available easy-to-use

software 'EZR' for medical statistics. Bone Marrow Transplant 48 : 452-458, 2013
30. Frontera WR, Hughes VA, Fielding RA, Fiatarone MA, Evans WJ, Roubenoff R : Aging of skeletal muscle : a 12-yr longitudinal study. J Appl Physiol 88 : 1321-1326, 2000
31. Visser M, Kritchevsky SB, Goodpaster BH, Newman AB, Nevitt M, Stamm E, Harris TB : Leg muscle mass and composition in relation to lower extremity performance in men and women aged 70 to 79 : the health, aging and body composition study. J Am Geriatr Soc 50 : 897-904, 2002
32. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, Jang HC, Kang L, Kim M, Kim S, Kojima T, Kuzuya M, Lee JSW, Lee SY, Lee WJ, Lee Y, Liang CK, Lim JY, Lim WS, Peng LN, Sugimoto K, Tanaka T, Won CW, Yamada M, Zhang T, Akishita M, Arai H : Asian working group for sarcopenia : 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med 21 : 300-307.e2, 2020
33. MacRae PG ; Feltner ME, Reinsch S : A 1-year exercise program for older women : effects on falls, injuries, and physical performance. J Aging Physic Act 2 : 127-142, 1994
34. Means KM, Rodell DE, O'Sullivan PS, Cranford LA : Rehabilitation of elderly fallers : pilot study of a low to moderate intensity exercise program. Arch Phys Med Rehabil 77 : 1030-1036, 1996
35. Chin A Paw MJ, van Poppel MN, Twisk JW, van Mechelen W : Once a week not enough, twice a week not feasible? A randomised controlled exercise trial in long-term care facilities [ISRCTN87177281]. Patient Educ Couns 63 : 205-214, 2006
36. Stiggelbout M, Popkema DY, Hopman-Rock M, de Greef M, van Mechelen W : Once a week is not enough : effects of a widely implemented group based exercise program for older adults ; a randomized controlled trial. J Epidemiol Community Health 58 : 83-88, 2004
37. Nilsson MI, Dobson JP, Greene NP, Wiggs MP, Shimkus KL, Wudeck EV, Davis AR, Laureano ML, Fluckey JD : Abnormal protein turnover and anabolic resistance to exercise in sarcopenic obesity. FASEB J 27(10) : 3905-3916, 2013
38. Guillet C, Boirie Y : Insulin resistance : a contributing factor to age-related muscle mass loss?. Diabetes Metab 31 : 5S20-5S26, 2005
39. Dramé M, Godaert L : The obesity paradox and mortality in older adults : a systematic review. Nutrients 15 : 1780, 2023
40. Eitmann S, Matrai P, Hegyi P, Balasko M, Eross B, Dorogi K, Petervari E : Obesity paradox in older sarcopenic adults - a delay in aging : a systematic review and meta-analysis. Ageing Res Rev 93 : 102164, 2024
41. Karagun B, Baklaci N : Comparative analysis of basal metabolic rate measurement methods in overweight and obese individuals : a retrospective study. Medicine 103 : e39542, 2024
42. Flakoll P, Sharp R, Baier S, Levenhagen D, Carr C, Nissen S : Effect of beta-hydroxy-beta-methylbutyrate, arginine, and lysine supplementation on strength, functionality, body composition, and protein metabolism in elderly women. Nutrition 20 : 445-451, 2004
43. Tieland M, Dirks ML, van der Zwaluw N, Verdijk LB, van de Rest O, de Groot LC, van Loon LJ : Protein supplementation increases muscle mass gain during prolonged resistance-type exercise training in frail elderly people : a randomized, double-blind, placebo-controlled trial. J Am Med Dir Assoc 13 : 713-719, 2012
44. Zdzieblik D, Oesser S, Baumstark MW, Gollhofer A, König D : Collagen peptide supplementation in combination with resistance training improves body composition and increases muscle strength in elderly sarcopenic men : a randomized controlled trial. Br J Nutr 114 : 1237-1245, 2015
45. Tan B, Su H, Wei L, Liang M : Association of dietary patterns with osteoporosis risk : a meta-analysis of observational studies. J Orthop Surg Res 20 : 551, 2025
46. Kaushal N, Langlois F, Desjardins-Crépeau L, Hagger MS, Bherer L : Investigating dose-response effects of multimodal exercise programs on health-related quality of life in older adults. Clin Interv Aging 14 : 209-217, 2019
47. Yamamoto S, Ishii D, Ishibashi K, Okamoto Y, Kawamura K, Takasaki Y, Tagami M, Tanamachi K, Kohno Y : Combined exercise and education program : effect of smaller group size and longer duration on physical function and social engagement among community-dwelling older adults. JAR Life 12 : 56-60, 2023

Supplementary Materials 1. Comparison before-and-after exercise intervention (HR, n=25)

Variable	Unit	Pre	Post	p-value	ES (r-value)	Hodges-Lehmann median difference (95%CI)	Venues B (reference Venues A)†			Venues C (reference Venues A)†		
							β	95%CI	p-value	β	95%CI	p-value
Body composition												
Height	cm	153.8 ± 8.2	154.0 ± 8.3	0.026*	0.45	0.25 (0.05 to 0.40)	0.11	−0.28 to 0.51	0.56	0.33	−0.16 to 0.82	0.177
Weight	kg	53.9 ± 9.5	54.3 ± 9.4	0.071	0.37	0.45 (–0.05 to 1.00)	—	—	—	—	—	—
BMI	%	22.7 ± 3.4	22.8 ± 3.3	0.32	0.21	0.15 (–0.10 to 0.35)	—	—	—	—	—	—
SMI	kg/m²	6.6 ± 0.7	6.6 ± 0.6	0.21	−0.27	−0.10 (–0.20 to 0.05)	—	—	—	—	—	—
MM	kg	36.4 ± 6.5	36.2 ± 6.3	0.119	−0.31	−0.30 (–0.60 to 0.10)	—	—	—	—	—	—
Leg muscle score	point	84.8 ± 7.8	85.2 ± 9.1	0.59	0.11	0.50 (–2.00 to 3.00)	—	—	—	—	—	—
Estimated bone mass	kg	2.0 ± 0.4	2.0 ± 0.4	0.62	−0.12	−0.00 (–0.10 to 0.05)	—	—	—	—	—	—
BMR	kcal	1065.9 ± 163.8	1062.4 ± 158.8	0.27	−0.22	−6.00 (–15.50 to 5.50)	—	—	—	—	—	—
FM	kg	15.5 ± 5.8	16.2 ± 5.7	0.022*	0.47	0.65 (0.15 to 1.20)	0.30	−0.90 to 1.50	0.61	0.65	−0.82 to 2.12	0.37
Body fat percentage	%	28.3 ± 7.8	29.3 ± 7.3	0.017*	0.48	1.10 (0.25 to 1.85)	0.86	−0.94 to 2.67	0.33	1.11	−1.06 to 3.28	0.30
Visceral fat level		8.2 ± 4.0	8.1 ± 4.3	0.66	−0.10	−0.00 (–1.00 to 1.00)	—	—	—	—	—	—
Whole-body muscle score		−0.8 ± 1.2	−0.9 ± 1.2	0.182	−0.28	−1.00 (–1.00 to –0.00)	—	—	—	—	—	—
PA Whole body	°	4.5 ± 0.5	4.8 ± 0.7	0.038*	0.42	0.30 (0.00 to 0.65)	−0.13	−0.76 to 0.50	0.67	−0.65	−1.44 to 0.14	0.103
PA Both arms	°	5.0 ± 0.5	5.1 ± 0.6	0.55	0.12	0.05 (–0.15 to 0.25)	—	—	—	—	—	—
PA Both lower limbs	°	4.0 ± 0.7	4.1 ± 0.7	0.066	0.37	0.20 (–0.00 to 0.35)	—	—	—	—	—	—
Physical function												
HG	kg	26.5 ± 6.8	29.3 ± 6.9	< 0.001*	0.76	2.60 (1.55 to 3.60)	−2.55	−5.08 to −0.02	0.048*	−2.44	−5.80 to 0.91	0.145
GS	m/s	2.0 ± 0.4	2.4 ± 0.4	< 0.001*	0.72	0.35 (0.20 to 0.50)	0.16	−0.11 to 0.42	0.24	−0.33	−0.66 to −0.00	0.049*
CS	s	7.8 ± 2.1	7.2 ± 2.3	0.097	−0.33	−0.55 (–1.12 to 0.15)	—	—	—	—	—	—
SLS	s	45.0 ± 44.3	44.9 ± 43.0	0.64	0.10	2.79 (–13.50 to 15.50)	—	—	—	—	—	—

Pre, before exercise intervention ; Post, after exercise intervention ; ES, effect size ; BMI, body mass index ; SMI, skeletal muscle mass index ; MM, muscle mass ; BMR, basal metabolic rate ; FM, fat mass ; PA, phase angle ; HG, handgrip strength ; GS, gait speed ; CS, chair stand test ; SLS, single-leg stance ; y/o, years old. The criteria for ES were a small effect size, r-value >0.10 ; a medium effect size, r-value >0.30 ; and a large effect size, r-value >0.50. The criteria for the power value : 0.8. *p-value <0.05. †Sensitivity analysis was performed using multiple linear regression with post-intervention value as the dependent variable and baseline value and venue as independent variables.

Supplementary Materials 2. Comparison before-and-after exercise intervention (LR, n=40)

Variable	Unit	Pre	Post	p-value	ES (r-value)	Hodges-Lehmann median difference (95%CI)	Venues B (reference Venues A)†			Venues C (reference Venues A)†		
							β	95%CI	p-value	β	95%CI	p-value
Body composition												
Height	cm	155.9 ± 6.8	156.0 ± 6.7	0.105	0.26	0.15 (–0.05 to 0.35)	—	—	—	—	—	—
Weight	kg	54.6 ± 8.7	54.7 ± 8.7	0.73	0.05	0.05 (–0.25 to 0.40)	—	—	—	—	—	—
BMI	%	22.5 ± 3.2	22.5 ± 3.1	0.77	−0.04	−0.05 (–0.20 to 0.15)	—	—	—	—	—	—
SMI	kg/m²	7.0 ± 0.8	6.8 ± 0.8	< 0.001*	−0.64	−0.20 (–0.25 to –0.10)	0.04	−0.18 to 0.26	0.71	0.06	−0.14 to 0.25	0.56
MM	kg	37.2 ± 6.3	36.7 ± 6.0	< 0.001*	−0.59	−0.55 (–0.80 to –0.30)	0.36	−0.34 to 1.06	0.31	0.47	−0.16 to 1.09	0.139
Leg muscle score	point	92.8 ± 8.9	92.2 ± 8.8	0.082	−0.28	−1.50 (–2.50–0.00)	—	—	—	—	—	—
Estimated bone mass	kg	2.2 ± 0.3	2.1 ± 0.3	0.003*	−0.47	−0.10 (–0.15 to –0.10)	0.04	−0.05 to 0.12	0.38	0.05	−0.02 to 0.13	0.138
BMR	kcal	1108.1 ± 160.8	1095.2 ± 155.6	< 0.001*	−0.56	−13.00 (–19.50 to –6.50)	12.14	−6.40 to 30.69	0.192	14.33	−2.05 to 30.71	0.084
FM	kg	15.2 ± 5.9	15.9 ± 5.6	0.001*	0.51	0.65 (0.25 to 0.95)	0.16	−1.02 to 1.34	0.79	−0.37	−1.42 to 0.68	0.48
Body fat percentage	%	27.5 ± 7.8	28.7 ± 7.2	< 0.001*	0.60	1.25 (0.70 to 1.80)	0.26	−1.51 to 2.02	0.77	−0.38	−1.95 to 1.18	0.62
Visceral fat level		6.6 ± 3.5	6.8 ± 3.6	0.103	0.26	1.00 (–0.00 to 1.00)	—	—	—	—	—	—
Whole-body muscle score		−0.2 ± 1.2	−0.5 ± 1.2	0.003*	−0.47	−1.00 (–1.00 to –1.00)	0.50	−0.06 to 1.05	0.078	0.32	−0.18 to 0.81	0.20
PA Whole body	°	4.9 ± 0.5	4.9 ± 0.6	0.70	0.04	0.00 (–0.10 to 0.15)	—	—	—	—	—	—
PA Both arms	°	5.2 ± 0.6	5.3 ± 0.6	0.48	0.08	0.05 (–0.10 to 0.15)	—	—	—	—	—	—
PA Both lower limbs	°	4.5 ± 0.6	4.5 ± 0.6	0.180	0.21	0.08 (–0.05 to 0.15)	—	—	—	—	—	—
Physical function												
HG	kg	28.6 ± 6.6	30.3 ± 6.4	0.002*	0.48	1.70 (0.70 to 2.45)	−2.62	−5.20 to −0.03	0.047*	−3.12	−5.37 to −0.87	0.008*
GS	m/s	2.3 ± 0.4	2.6 ± 0.5	< 0.001*	0.64	0.25 (0.15 to 0.35)	0.01	− 0.30 to 0.32	0.96	−0.21	− 0.48 to 0.07	0.133
CS	s	7.5 ± 1.9	6.4 ± 1.5	< 0.001*	−0.62	−1.10 (–1.60 to –0.65)	−0.11	−1.36 to 1.14	0.85	−0.45	−1.57 to 0.68	0.42
SLS	s	72.5 ± 48.4	76.1 ± 46.2	0.57	0.09	4.00 (–13.50 to 25.00)	—	—	—	—	—	—

Pre, before exercise intervention ; Post, after exercise intervention ; ES, effect size ; BMI, body mass index ; SMI, skeletal muscle mass index ; MM, muscle mass ; BMR, basal metabolic rate ; FM, fat mass ; PA, phase angle ; HG, handgrip strength ; GS, gait speed ; CS, chair stand test ; SLS, single-leg stance ; y/o, years old. The criteria for ES were a small effect size, r-value >0.10 ; a medium effect size, r-value >0.30 ; and a large effect size, r-value >0.50. The criteria for the power value : 0.8. *p-value <0.05. †Sensitivity analysis was performed using multiple linear regression with post-intervention value as the dependent variable and baseline value and venue as independent variables.