

Original Article

## Enhancing Mobility and Reducing Falls in Frail Older Adults with Vivifrail Training Guidance in an Integrated Care Model

Wei-Cheng Su<sup>a</sup>, Mei-Lan Hsiao<sup>b</sup>, Yi-Wen Huang<sup>c</sup>, Tzu-Yi Yang<sup>c</sup>, Hui-Min Lin<sup>d</sup>, Sheng-Lun Kao<sup>a,e\*</sup>

<sup>a</sup> Department of Family Medicine, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan, <sup>b</sup> Department of Nursing, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan, <sup>c</sup> Department of Rehabilitation Medicine, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan, <sup>d</sup> Department of Nutrition, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan, <sup>e</sup> Department of Family Medicine, School of Medicine, Tzu Chi University, Hualien, Taiwan

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### SUMMARY

**Background:** Frailty is associated with reduced mobility and a higher risk of falls. This study examined the impact of integrated care, particularly Vivifrail-based training guidance, on the mobility and fall incidence in frail patients.

**Methods:** This retrospective observational study included pre-frail or frail individuals aged  $\geq 55$  years attending a geriatric clinic. The integrated care model involved geriatric assessment, case management, and Vivifrail-based physical training guidance. Data were collected before and after a 2-month program focusing on geriatric assessment components, mobility, exercise habits, and fall incidence. Changes were assessed using the Wilcoxon signed-rank and McNemar tests.

**Results:** Among the 62 participants (average age:  $77.2 \pm 8.8$  years; 56.5% females), significant improvements were observed during follow-up. The Mini Nutritional Assessment Short-Form scores increased from 10.0 (interquartile range [IQR]: 2.0) to 12.0 (IQR: 3.0) ( $p < 0.001$ ). Mobility improved, with Short Physical Performance Battery scores rising from 8.0 (IQR: 5.5) to 9.0 (IQR: 7.2) ( $p = 0.020$ ) and 4 m gait speed improving from 0.60 m/s to 0.73 m/s ( $p = 0.025$ ). Establishing exercise habits over the past month increased significantly from 25 (40.3%) to 44 individuals (71.0%) ( $p < 0.001$ ). Meanwhile, the incidence of falls over the previous three months decreased from 23 (37.1%) to 12 individuals (19.4%) ( $p = 0.019$ ).

**Conclusion:** This study emphasizes that an integrated care model with Vivifrail-based training guidance may enhance mobility and reduce the risk of falls in pre-frail and frail older adults.

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## 1. Introduction

Frailty is a common condition in older adults, increasing their vulnerability to stressors due to reduced physiological reserves.<sup>1</sup> A pioneering study by Fried et al. identified frailty as a syndrome characterized by unintentional weight loss, weakness, exhaustion, slowness, and low physical activity.<sup>2</sup> These features increase the risk of adverse health outcomes, including disability, hospitalization, and mortality.<sup>3</sup> Frailty can also cause impaired mobility and higher fall risk, significantly impacting the independence, well-being, and overall quality of life of affected individuals.<sup>3–5</sup>

Despite the significant health risks associated with frailty, integrated care models have emerged as a highly promising approach for addressing the complex needs of frail patients.<sup>6–8</sup> Integrated care models, particularly those with exercise training, can effectively enhance the quality of life and functionality of frail older adults.<sup>9,10</sup> Including Vivifrail-based exercise training guidance, designed for frail older adults, may enhance physical activity, strengthen muscles, and improve balance, thereby reducing the risk of falls.<sup>11,12</sup> Álvaro Casas-Herrero et al. conducted a multicenter, randomized controlled trial,

demonstrating that the Vivifrail program effectively and safely enhances functional capacity in community-dwelling frail/pre-frail older patients with mild cognitive impairment or mild dementia. The program also showed potential benefits for cognition, muscle function, and mood. However, the study included only exercise training and did not show significant differences in fall rates.<sup>13</sup>

Despite the availability of such training programs, the effectiveness of integrated care combined with Vivifrail training guidance in improving exercise habits and reducing falls in older adults remains underexplored. Therefore, we aimed to investigate the impact of integrated care with Vivifrail-based exercise training guidance on mobility and fall incidence in frail older adults.

## 2. Materials and methods

### 2.1. Study design and setting

This retrospective observational study was conducted at the geriatric clinic of Hualien Tzu Chi Hospital between March 1 and December 31, 2022. Using a convenience sampling, we enrolled pre-frail and frail patients with impaired mobility or risk of falls during their clinic visits. These patients were evaluated and enrolled in a frailty-integrated care model that included Vivifrail exercise training

\* Corresponding author. Department of Family Medicine, Hualien Tzu Chi Hospital, No. 707, Sec. 3, Chung Yang Rd., Hualien 970, Taiwan.

E-mail address: [stevenkao7434@gmail.com](mailto:stevenkao7434@gmail.com) (S.-L. Kao)

guidance, facilitated by a multidisciplinary team comprising a board-certified geriatrician (S.L.K.), a trained geriatric case manager (M.L.H.), a clinical dietitian (H.M.L.), and physical therapists (Y.W.H. and T.Y.Y.).

Pre- and post-tests were conducted two months apart. The data collected included measures of baseline characteristics (age, sex, number of comorbidities, and body mass index), geriatric assessment components, and mobility data. Comorbidities included diabetes, hypothyroidism, osteoarthritis, osteoporosis, asthma, chronic obstructive pulmonary disease, chronic kidney disease, stroke, hypertension, ischemic heart disease, heart failure, peripheral artery disease, hyperlipidemia, and arrhythmia. The geriatric assessment components included activities of daily living (ADL),<sup>14</sup> Lawton instrumental ADL (IADL),<sup>15</sup> Geriatric Depression Scale-15 (GDS-15),<sup>16</sup> and Mini Nutritional Assessment - Short Form (MNA-SF).<sup>17</sup> Mobility was assessed using the Short Physical Performance Battery (SPPB), 4-meter gait speed, and the five-time chair stand test.<sup>18</sup> All assessment tools used in this study are validated and widely accepted in geriatric research. For example, the SPPB, GDS-15, and MNA-SF have demonstrated moderate but acceptable internal consistency (Cronbach's  $\alpha = 0.76, 0.75,$  and  $0.73$ ), with good validity.<sup>16–18</sup> We also used a standardized questionnaire to assess participants' exercise habits in the past month and fall incidence in the previous three months.

The Institutional Review Board of Hualien Tzu Chi Hospital (IRB 113-078-B) approved this study, and informed consent was waived as the study only involved the review of medical records.

## 2.2. Study population

Potentially eligible outpatients were initially evaluated by a geriatrician. We focused on a vulnerable population aged  $\geq 55$  years, classified as pre-frail or frail, with sufficient functional and cognitive reserves to complete the intervention program. All consecutive patients who met the criteria and exhibited impaired mobility or risk of falls during the study period were enrolled.

Inclusion criteria required participants to have a Clinical Frailty Scale (CFS) score of 4–7.<sup>19</sup> Mobility was evaluated using the SPPB, where scores of  $\leq 9$  indicated impaired mobility.<sup>18</sup> Additionally, fall risk was assessed based on criteria from the Vivifrail training program, which included one of the following conditions: experiencing two or more falls in the past year, a timed up-and-go performance of  $\geq 20$  s, or a 6-meter walking speed of  $\geq 7.5$  s.<sup>11,12</sup>

Participants who were completely dependent, nearing the end of life (CFS scores of 8–9), or those who did not complete the intervention program or follow-up assessments, were excluded from the study.

## 2.3. Integrated care model with Vivifrail training guidance

Initially, a board-certified geriatrician, a trained geriatric case manager, and a clinical dietitian interviewed the patients. The geriatrician and the case manager performed geriatric assessment and medication review in an outpatient setting. The clinical dietitian evaluated the participants' nutritional status, addressing any issues and providing education on the recommended daily caloric and protein intake.

Next, participants were assigned to Vivifrail levels based on their SPPB scores: Level A (0–3), B (4–6), C (7–9), or D (10–12). Exercise sessions were conducted at least three times weekly and comprised multicomponent training, focusing on strength, balance, flexibility, and endurance. For Level A (lowest function), the program emphasized developing an exercise habit and improving basic mobility, starting with short bouts of assisted walking ( $5\text{--}10 \text{ s} \times 5$  sets,

gradually increasing to 1–2 min), simple strength exercises (e.g., lifting a bottle, squeezing a ball, and sit-to-stand with assistance; 12 repetitions  $\times$  3 sets), and stretching. Level B participants performed walking at a moderate pace (2 min  $\times$  5 sets, progressing to 3 sets of 8 min from week 7), strength exercises (12 repetitions  $\times$  3 sets), balance tasks (toe/heel walking), and arm stretches. Level C involved longer walking durations (10 min  $\times$  3 sets, progressing to 15 min), more advanced strength and balance exercises (e.g., towel twisting, chair rises, figure-8 walking, obstacle course), and stretching. Level D (highest function) focused on prolonged walking (20 min  $\times$  2 sets, progressing to 30–45 min), stair climbing, balloon walking, and other advanced balance and strength activities with stretching. Intensity was individualized; the walking pace was set so that participants could maintain a conversation while still experiencing exertion, and therapists adjusted resistance or complexity as needed. These could be further tailored by physical therapists to ensure both safety and progression.

Fall prevention guidance was provided for patients at risk of falls. Comorbidities, medication use, and nutritional status were evaluated. Additional assessments included checking for postural hypotension, evaluating the use of foot and assistive devices, and conducting home environment risk assessments to ensure that participants received adequate vitamin D and calcium supplements.

Throughout the training program, case managers made at least one phone call to confirm the status of the home interventions. Intensive communication occurred among geriatricians, participants, team members, and families to monitor adherence to the protocol and implement necessary adjustments.

## 2.4. Statistical analysis

Sample size estimation was based on the primary outcome, which is the change in SPPB score. According to a previous study, the mean difference in SPPB was 0.86 (95% confidence interval [CI]: 0.32–1.41). Assuming a moderate effect size (Cohen's  $d = 0.5$ ), a paired t-test with a two-sided significance level of 0.05 and a power of 0.8 requires approximately 63 participants.<sup>13,20</sup>

Participants were categorized into those with and those without baseline exercise habits. Subsequently, we conducted analyses both for the entire patient cohort and separately for the groups with and without exercise habits. Descriptive statistics were used to evaluate baseline clinical and demographic characteristics, including median with interquartile range (IQR) and frequency (proportion), as appropriate.

Additionally, we used the Mann-Whitney U test and Fisher's exact test to assess differences between the groups, whereas the Wilcoxon signed-rank test was applied to examine changes in geriatric assessment components and mobility before and after the care program. We calculated the changes in exercise habits and fall incidence before and after the program using the McNemar test. A multivariate logistic regression analysis was conducted to assess the association between establishing an exercise habit during program training (adherence  $> 80\%$ ) and SPPB improvement or maintenance while controlling for age, sex, comorbidity count, and baseline SPPB score.

Statistical significance was set at a two-tailed p-value of  $< 0.05$ . All statistical analyses were performed using IBM SPSS Statistics for Windows version 22.

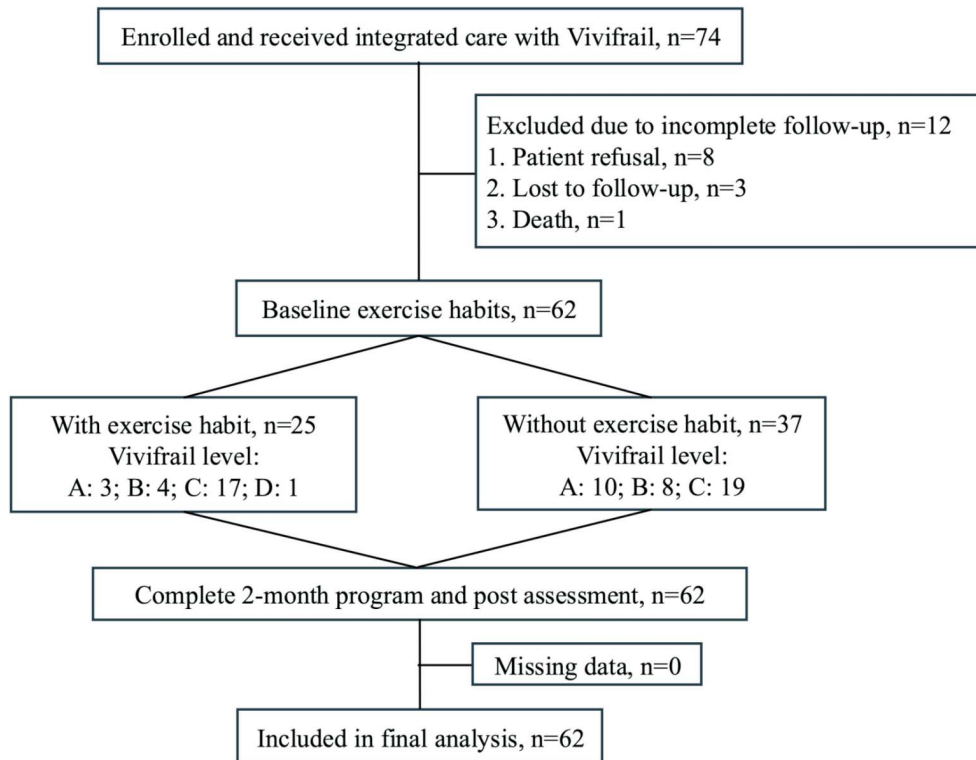
## 3. Results

We enrolled all consecutive patients aged  $\geq 55$  years, who met the criteria for pre-frailty or frailty and exhibited impaired mobility

or a risk of falls during the study period. Participants who were unable to complete the post-assessment, due to refusal, lost to follow-up, or death, were excluded from the final analysis ( $n = 12$ ). Consequently, 62 participants were included in the final analysis, with no missing values for any of the variables analyzed (Figure 1). The mean age was  $77.2 \pm 8.8$  years, with 35 women (56.5%) included. Participants were divided into two groups: those with and those without

exercise habits (Table 1). The exercise habit group consisted of 25 individuals (40.3%), whereas the non-exercise habit group included 37 individuals (59.7%). We analyzed the baseline characteristics and geriatric assessments of both groups, which showed no statistically significant differences.

In the 4-meter gait speed test, two participants (3.2%) from the non-exercise habit group were unable to complete the evaluation,



**Figure 1.** Flowchart of participant enrollment, intervention, and analysis in the integrated care model with Vivifrail training guidance.

**Table 1**

Baseline clinical and demographic characteristics of the prefrail and frail older patients with impaired mobility or fall risks in a primary care setting (2022).

	Total (n = 62)	Without exercise habits (n = 37)	With exercise habits (n = 25)	p-value
<b>Baseline characteristics</b>				
Age, years	77.0 (70.8, 83.0)	77.0 (68.5, 83.0)	78.0 (74.0, 83.5)	0.358
Sex, female (%)	35 (56.5)	24 (64.9)	11 (44.0)	0.124
Comorbidities	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	2.0 (1.0, 3.0)	0.088
<b>Geriatric assessment components</b>				
ADL	95.0 (80.0, 100.0)	90.0 (77.5, 95.0)	95.0 (85.0, 100.0)	0.080
Lawton IADL	4.5 (2.0, 7.0)	4.0 (2.0, 7.0)	5.0 (2.0, 8.0)	0.297
GDS-15	1.0 (0.0, 3.3)	2.0 (0.0, 3.0)	1.0 (0.0, 4.0)	0.614
MNA-SF	10.0 (9.0, 11.0)	10.0 (9.0, 11.0)	10.0 (9.5, 11.0)	0.516
BMI, kg/m <sup>2</sup>	23.4 (20.8, 26.9)	23.9 (21.1, 27.2)	23.2 (19.9, 26.1)	0.546
<b>Mobility</b>				
SPPB	8.0 (4.8, 10.3)	7.0 (2.0, 10.0)	9.0 (6.0, 10.5)	0.110
4 m gait speed				0.511
Complete	60 (96.8)	35 (94.6)	25 (100.0)	
Not complete	2 (3.2)	2 (5.4)	0 (0)	
4 m gait speed, m/sec <sup>a</sup>	6.7 (4.5, 10.4)	7.0 (4.5, 12.4)	6.3 (4.5, 8.6)	0.270
Five-time chair stand				<b>0.031*</b>
Complete	48 (77.4)	25 (67.6)	23 (92.0)	
Not complete	14 (22.6)	12 (32.4)	2 (8.0)	
Five-time chair stand, sec <sup>a</sup>	11.5 (9.0, 13.6)	12.0 (8.7, 15.2)	11.1 (9.7, 13.6)	0.796

Data are presented as medians (Q1 and Q3) or numbers (percentages).

\*  $p < 0.05$ .

<sup>a</sup> Participants who were unable to complete either the 4 m gait speed or the five-time chair stand test at baseline were not included in the statistical analysis.

ADL, activities of daily living; BMI, body mass index; GDS-15, geriatric depression scale-15; Lawton IADL, Lawton instrumental activities of daily living; MNA-SF, Mini Nutritional Assessment-Short Form; SPPB, Short Physical Performance Battery.

whereas all participants in the exercise habit group completed it. Fisher's exact test indicated no statistically significant differences between the two groups. In the five-time chair stand test, two individuals (8.0%) from the exercise habit group were unable to complete the evaluation compared with 12 individuals (32.4%) from the non-exercise habit group. Fisher's exact test revealed a statistically significant difference between the two groups ( $p = 0.031$ ).

Adherence to the Vivifrail training program was assessed through follow-up calls and post-intervention assessment by the case manager or physical therapist. Regular supervision, protocol checklists with written reminders, and video demonstrations were conducted to ensure fidelity. Participants who completed at least 80% of the prescribed sessions were classified as adherents (44 of the 62 participants [71%]). After integrating care with Vivifrail-based physical training guidance, significant improvements were observed in geriatric assessment components (Table 2). Particularly, notable enhancements in MNA-SF scores were observed, with median (IQR) values increasing from 10.0 (2.0) in the pre-test to 12.0 (3.0) in the post-test ( $p < 0.001$ ). Similarly, the GDS-15 showed improvement, with median (IQR) scores changing from 1.0 (3.3) pre-test to 0.0 (3.0) post-test ( $p = 0.001$ ). Mobility, measured using SPPB, also significantly improved, with median (IQR) scores increasing from 8.0 (5.5) to 9.0 (7.2) ( $p = 0.020$ ). The mean difference in SPPB scores between the two time points was 0.56 (95% CI: 0.074–1.055; standard deviation [SD] = 1.93;  $n = 62$ ), with an effect size (Cohen's  $d$ ) of 0.29, indicating a small to medium effect. Minimal clinically important difference (MCID) for SPPB was achieved in 29 participants (46.8%), defined as an improvement of at least 1 point.<sup>21</sup> Additionally, the 4-meter gait speed test improved from a median (IQR) of 0.60 (0.51) meters/second to 0.73 (0.61) meters/second ( $p = 0.025$ ).

The mean difference in 4-meter gait speed was 0.10 m/s (95% CI: 0.020–0.181; SD = 0.31;  $n = 59$ ), with an effect size (Cohen's  $d$ ) of 0.32, indicating a small to medium effect. A total of 28 participants (45.2%) achieved the MCID for gait speed, defined as an increase of at least 0.1 m/s.<sup>22</sup> The proportion of participants who could complete the five-

time chair stand test significantly increased from 48 (77.4%) to 51 (82.3%) ( $p < 0.001$ ). These results reflect significant enhancements in mood, nutrition, and mobility among the participants (Table 2).

Prior to the intervention, 23 (37.1%) of the 62 participants experienced falls, whereas only 12 (19.4%) experienced falls after the intervention ( $p = 0.019$ ), revealing a statistically significant difference (Table 2). Among the 23 individuals with a history of falls, 15 (65.2%) did not experience falls after the intervention. Additionally, after integrated care, the number of participants with exercise habits increased from 25 (40.3%) to 44 (71.0%) ( $p < 0.001$ ), with 22 (59.5%) of the 37 individuals in the non-exercise habit group developing new exercise habits. After adjusting for age, sex, comorbidity count, and baseline SPPB score, participants who established a regular exercise habit during program training (adherence > 80%) had significantly higher odds of SPPB improvement or maintenance than those who did not establish an exercise habit (odds ratio = 7.819, 95% CI: 1.425–42.912,  $p = 0.018$ ).

As shown in Table 3, when participants were divided into groups based on their exercise habits, significant improvements were observed in GDS-15 and MNA-SF scores in both groups after integrated care. Mobility assessments showed a significant increase in the five-time chair stand test for the group without exercise habits, from 25 (67.6%) to 29 (78.4%) ( $p = 0.008$ ). Meanwhile, the median (IQR) of SPPB scores improved from 9.0 (4.5) to 11.0 (5.5) in the group with exercise habits ( $p = 0.036$ ) (Table 3).

#### 4. Discussion

Our study provides compelling evidence for the benefits of an integrated care model with Vivifrail training guidance for frail older adults. Participants demonstrated significant improvements in GDS-15 and MNA-SF scores, reflecting improvements in mental health and nutritional status. Mobility assessments, including SPPB, 4-meter gait speed test, and five-time chair stand test, also demonstrated significant improvements. Notably, fall incidence decreased

**Table 2**

Components of the geriatric assessment, mobility, fall incidence, and exercise habits before and after the integration of care with Vivifrail-based physical training guidance for prefrail and frail older patients with impaired mobility or fall risks in a primary care setting (2022).

	Pre-test	Post-test	<i>p</i> -value
Geriatric assessment components			
ADL ( $n = 62$ )	95.0 (80.0, 100.0)	95.0 (80.0, 100.0)	0.146
Lawton IADL ( $n = 62$ )	4.5 (2.0, 7.0)	5.0 (2.0, 8.0)	0.167
GDS-15 ( $n = 62$ )	1.0 (0.0, 3.3)	0.0 (0.0, 3.0)	<b>0.001*</b>
MNA-SF ( $n = 62$ )	10.0 (9.0, 11.0)	12.0 (11.0, 14.0)	<b>&lt; 0.001*</b>
BMI ( $\text{kg}/\text{m}^2$ , $n = 62$ )	23.4 (20.8, 26.9)	23.0 (19.4, 26.3)	0.466
Mobility			
SPPB ( $n = 62$ )	8.0 (4.8, 10.3)	9.0 (4.8, 12.0)	<b>0.020*</b>
4 m gait speed			
Complete	60 (96.8)	61 (98.4)	1.000
Not complete	2 (3.2)	1 (1.6)	
4 m gait speed ( $\text{m}/\text{sec}$ , $n = 59$ ) <sup>a</sup>	0.60 (0.38, 0.89)	0.73 (0.42, 1.03)	<b>0.025*</b>
Five-time chair stand			
Complete	48 (77.4)	51 (82.3)	<b>&lt; 0.001*</b>
Not complete	14 (22.6)	11 (17.7)	
Five-time chair stand ( $\text{sec}$ , $n = 45$ ) <sup>a</sup>	11.3 (8.9, 13.5)	10.3 (8.5, 12.7)	0.343
Fall incidence and exercise habits			
Fall incidence	23 (37.1)	12 (19.4)	<b>0.019*</b>
Establish exercise habits	25 (40.3)	44 (71.0)	<b>&lt; 0.001*</b>

Data are presented as medians (Q1 and Q3) or numbers (percentages).

\*  $p < 0.05$ .

<sup>a</sup> Participants who were unable to complete either the 4 m gait speed or the five-time chair stand test at baseline or post-assessment were not included in the statistical analysis. The numbers of participants included in each analysis are indicated for each variable.

ADL, activities of daily living; BMI, body mass index; GDS-15, geriatric depression scale-15; Lawton IADL, Lawton instrumental activities of daily living; MNA-SF, Mini Nutritional Assessment-Short Form; SPPB, Short Physical Performance Battery.

**Table 3**

Components of the geriatric assessment, mobility, and fall incidence before and after the integration of care with Vivifrail-based physical training guidance for prefrail and frail older patients with and without baseline exercise habits in a primary care setting (2022).

	Without exercise habits (n = 37)		p-value	With exercise habits (n = 25)		p-value
	Pre-test	Post-test		Pre-test	Post-test	
Geriatric assessment components						
ADL	90.0 (77.5, 95.0)	95.0 (80.0, 97.5)	0.128	95.0 (85.0, 100.0)	95.0 (90.0, 100.0)	0.598
Lawton IADL	4.0 (2.0, 7.0)	5.0 (2.0, 7.0)	0.248	5.0 (2.0, 8.0)	5.0 (2.5, 8.0)	0.429
GDS-15	2.0 (0.0, 3.0)	0.0 (0.0, 3.0)	<b>0.021*</b>	1.0 (0.0, 4.0)	0.0 (0.0, 2.5)	<b>0.017*</b>
MNA-SF	10.0 (9.0, 11.0)	12.0 (11.0, 14.0)	<b>&lt; 0.001*</b>	10.0 (9.5, 11.0)	13.0 (11.0, 14.0)	<b>&lt; 0.001*</b>
BMI (kg/m <sup>2</sup> )	23.9 (21.2, 27.2)	23.0 (20.0, 26.5)	0.829	23.2 (19.9, 26.1)	22.2 (18.8, 26.3)	0.208
Mobility						
SPPB	7.0 (2.0, 10.0)	8.0 (3.0, 10.0)	0.205	9.0 (6.0, 10.5)	11.0 (6.5, 12.0)	<b>0.036*</b>
4 m gait speed <sup>a</sup> (m/sec)	0.58 (0.32, 0.91) (n = 34)	0.71 (0.38, 0.91)	0.086	0.64 (0.47, 0.89) (n = 25)	0.80 (0.45, 1.06)	0.174
5-time chair stand <sup>a</sup> (sec)	12.3 (8.7, 17.0) (n = 23)	10.3 (8.5, 13.8)	0.362	11.1 (9.6, 12.9) (n = 22)	10.4 (8.9, 12.6)	0.626
Fall incidence						
Fall incidence (%)	13 (35.1)	7 (18.9)	0.213	10 (40.0)	5 (20.0)	0.121

Data are presented as medians (Q1 and Q3) or numbers (percentages).

\*  $p < 0.05$ .

<sup>a</sup> Participants who were unable to complete either the 4-meter walk test or the five-time sit-to-stand test at baseline or post-assessment were excluded from the statistical analysis. The numbers of participants included in each analysis are indicated for each variable.

ADL, activities of daily living; BMI, body mass index; GDS-15, geriatric depression scale-15; Lawton IADL, Lawton instrumental activities of daily living; MNA-SF, Mini Nutritional Assessment-Short Form; SPPB, Short Physical Performance Battery.

from 37.1% to 19.4%, highlighting the effectiveness of an integrated care model with fall prevention guidance.

These findings suggest that our integrated approach addresses both physical health and mental well-being. The observed reduction in depressive symptoms may be attributed to the positive effects of habitual exercise on mood and well-being, as documented in previous studies.<sup>23,24</sup> Exercise has been shown to increase self-efficacy and self-esteem, and may reduce the need for medication in individuals with depression.<sup>25</sup> Regarding nutritional status, physical activity can stimulate appetite and improve gastrointestinal function, potentially leading to enhanced dietary intake and better nutritional status in older adults.<sup>26</sup> Adequate nutrition is vital for maintaining muscle mass and strength, which is essential for preventing falls and improving overall physical performance.<sup>25</sup> The FRIEND study (Frailty Reduction via the Implementation of Exercise, Nutrition, and Deprescribing), which combined anabolic exercise with refining medications and nutrition, enhanced physical function and reduced fall rates.<sup>27</sup> However, although the FRIEND study primarily focused on residential aged care, our approach targeted the primary care setting, and improvements in nutritional risk were also observed.

Improvements in physical performance were significant in the SPPB, 4-meter gait speed test, as well as in completing a five-time chair stand in our study. These results are consistent with those of Álvaro Casas-Herrero et al., who demonstrated in a multicenter randomized controlled trial that the Vivifrail exercise program significantly improved the functional capacity and mood in community-dwelling frail older adults with mild cognitive impairment or dementia.<sup>13</sup> Additionally, a recent 12-month cluster randomized controlled trial by Liu et al. in elderly nursing homes revealed that integrated exercise interventions significantly improved frailty status and gait parameters.<sup>9</sup> These high-quality, longer-duration, controlled studies provide an important context for our findings and highlight the need for further robust research. We identified that frail older adults without exercise habits were less likely to complete the five-time chair stand task than those with regular exercise habits. The Vivifrail-based exercise guidance program typically begins with progressive resistance training, focusing on fundamental movements such as standing up from a seated position, as this is essential for supporting body weight. This approach is consistent with sequential exercise programming for frail individuals, which prioritizes exercises

tailored to the physical demands required for mobility.<sup>25</sup> Notably, significant improvements in the completion of the five-time chair stand were observed in the non-exercising group after the intervention in the current study.

Although a previous study using the Vivifrail exercise program did not show significant differences in fall risk,<sup>13</sup> our study revealed a substantial decrease in falls from 37.1% to 19.4%. Among participants with a history of falls, 15 of 23 (65.2%) reported no further incidents after the intervention. The significant reduction in fall incidence may be attributed to fall prevention guidance for patients at risk of falls. This aligns with a systematic review conducted by Suzanne M Dyer et al., which indicated that exercise likely reduces the rate of falls.<sup>28</sup> Our results reinforce the notion that structured exercise programs, particularly those focusing on balance, strength training, and fall prevention, may effectively mitigate fall risk in older adults.

The strength of our study lies in its multidisciplinary integrated care approach, which combines geriatric assessment, case management, and Vivifrail-based physical training guidance to provide a holistic strategy for improving health outcomes in frail older adults. The use of validated assessment tools such as the GDS-15, MNA-SF, SPPB, and gait speed tests adds robustness to our findings. However, our study has some limitations. First, the retrospective observational design may introduce potential biases, and the relatively small sample size may limit the generalizability of our findings. Second, both falls and exercise adherence were assessed using self-reported data, which introduces substantial risks of recall bias and social desirability bias, particularly in older adults. Although regular follow-up was implemented to mitigate recall bias, self-reporting is known to underestimate the incidence of falls and overestimate adherence rates. Therefore, the observed 71% adherence rate may be overestimated, and the true relationship between adherence and outcomes remains uncertain. Future studies should employ more robust and objective assessment methods — such as using falls diaries with regular telephone follow-up, and accelerometer-based activity monitoring — to enhance data accuracy and reliability. Third, the generalizability and implementation of this integrated care model are limited by several factors. The study was conducted in a single hospital in Taiwan, where resources and staffing may differ from other settings. Although all team members received pre-intervention training, we could not accurately estimate training costs. Differences in healthcare infrastruc-

ture, staff time, and equipment requirements may also affect implementation elsewhere. Scalability and sustainability remain challenging, particularly in resource-limited or differently structured systems. Although an 84% follow-up rate is acceptable for older adults, attrition may still affect feasibility and generalizability. Future research should explore ways to improve retention and identify which patient subgroups benefit most from intensive interventions. Fourth, since all participants received the same combination of interventions (case management, physical therapy supervision, and nutritional assessment), we are unable to determine the specific impact of each individual component, such as Vivifrail. This limits the ability to recommend particular elements for clinical practice. Future studies should consider designs that allow for analysis of individual components or subgroups to better understand the contribution and cost-effectiveness of each part of the integrated care model. Finally, although our findings revealed improvements following the intervention, the absence of a control group makes it challenging to attribute these improvements solely to the intervention. Future studies should incorporate appropriate control groups and, ideally, employ larger-scale randomized controlled trials to validate our findings and further investigate the long-term effects of integrated care models in frail older adults. Accordingly, our current results should be interpreted as preliminary evidence requiring further validation.

In conclusion, although our study emphasizes that an integrated care approach incorporating Vivifrail-based exercise training guidance may offer potential benefits for frail older adults — such as improved mood, mobility, and reduced fall incidence — these findings should be interpreted as preliminary. As a pilot feasibility study with inherent limitations, our results primarily serve to inform the design and implementation of future research. Larger, well-controlled trials are needed to validate these observations and to establish the effectiveness and long-term impact of integrated care models in this population.

### Ethics approval

This study was designed and conducted in accordance with the principles of the 1964 Declaration of Helsinki. The study was approved by the Institutional Review Board of Hualien Tzu Chi Hospital, Taiwan (IRB113-078-B). Informed consent was not required as the study involved a review of medical records.

### Availability of data and materials

The datasets generated in the current study are available from the corresponding author upon request.

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### Declaration of any potential financial and non-financial conflicts of interest

There are no conflicts of interest to declare.

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