



Citizen-Led Integrated Care in Rural Depopulation Areas: Addressing Depression and Frailty in Older Adults

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Background: Rural areas in Korea are experiencing both super-aging and depopulation, creating critical gaps in health and social care. Using a citizen participatory approach, we sought to address the care gaps for older adults in rural areas. This study examined the changes in frailty and depressive symptoms observed during a citizen-led intervention. **Methods:** This study is a single-arm pre-post quasi-experimental design. A 12-week intervention was implemented using local citizens as care providers. Intervention components included identifying and planning individual care needs, providing health education, organizing tailored community activities, and conducting AI-assisted weekly check-up calls to monitor health status. **Results:** Changes appeared more pronounced among vulnerable subgroups. Older adults with frailty showed an observed decrease in depressive symptoms compared to those with prefrailty or robust status. Conversely, among those with depressive symptoms, frailty levels appeared to increase more slowly than those without depressive symptoms. These patterns are consistent with the previously reported bidirectional associations between frailty and depression and may reflect the tendency for changes in one domain to coincide with changes in the other, rather than indicating a causal influence. **Conclusion:** This citizen-led care intervention showed more noticeable short-term changes among older adults with higher vulnerability, particularly those with frailty or depressive symptoms. These findings indicate potential roles for citizen participation in enhancing social support and supporting ongoing monitoring in rural depopulation areas. The results suggest that citizen participation is a potentially feasible and sustainable approach to care systems in aging, resource-limited communities.

Key Words: Rural population, Frailty, Depression, Citizen science, Aging in place

INTRODUCTION

Korea's rapid transition into a super-aged society, along with the accelerating depopulation of rural regions, has heightened concerns about the sustainability of care systems. A central question arises: who will deliver and coordinate care for older adults living in depopulated rural communities?

Rural areas face severe infrastructure deficiencies and limited access to essential services, including food, housing, and daily necessities.¹⁾

Depopulation regions experience shortages of medical services^{2,3)} and reduced opportunities for education and employment.⁴⁾ Poor transportation systems hinder access to medical facilities³⁾ and shopping centers.⁵⁾ The decline in commercial establishments has further restricted residents' access to food.⁶⁾

Older adults in rural areas differ from their urban counterparts. Rural environments characterized by low socioeconomic status, limited medical and recreational facilities⁷⁻⁹⁾ contribute to a higher prevalence of frailty among rural older adults compared to their ur-

ban counterparts.¹⁰⁾ Frailty is closely associated with depressive symptoms¹⁰⁻¹²⁾ because both conditions share similar pathological mechanisms.¹³⁾ Individuals with frailty are more likely to experience loneliness, which can lead to depressive symptoms¹⁴⁾ and further worsening of frailty.¹⁵⁾ These findings highlight the persistent rural-urban health gap and emphasize the need for broader, context-specific indicators when assessing health status.¹⁶⁾

Given that rural areas and older adults have distinct characteristics,¹⁷⁾ and considering local budget constraints and low financial independence, applying a uniform formal care system across all regions remains challenging.¹⁸⁾ Proposed solutions include establishing converged care centers that use space more efficiently,¹⁹⁾ expanding visiting nursing and home-based medical services,^{1,20)} strengthening linkages with existing health and welfare programs, and utilizing informal care resources, such as citizen participation.²⁾

A growing body of research highlights the importance of citizen participatory approaches in addressing care gaps in rural communities, where health and social welfare resources are scarce.^{21,22)} Studies show that locally driven, community-participatory delivery systems—integrating health, social, and welfare functions—play a pivotal role in bridging these gaps by mobilizing local resources, strengthening social networks, and fostering mutual support among residents.²³⁾ These systems improve continuity and accessibility of care²⁴⁾ and promote community empowerment and sustainability within integrated care systems.^{22,25)}

In Korea, many local governments have implemented citizen-participatory care programs to address community health issues.²⁶⁻²⁸⁾ However, these programs have primarily focused on identifying at-risk households or promoting general health improvement, rather than positioning citizens as active agents within a healthcare system. Existing service structures also show gaps in systematic needs assessment and care planning.^{29,30)}

The citizen-led approaches in this study were grounded in direct interactions with older adults through care planning and management, frailty education, and activities that promote social engagement. To ensure continuous monitoring, we incorporated an AI-based check-in call system.

In Korea, existing AI-assisted services—such as programs for preventing solitary death³¹⁾ and AI-IoT health management services for older adults³²⁾—automatically collect health-related data and detect changes in individuals' conditions.³³⁾ However, these services offer limited customization³³⁾ and provide minimal feedback and relational engagement,³¹⁾ even though older adults need interactive systems.³²⁾ Moreover, the role of human providers remains essential for fulfilling the needs identified by AI-assisted services and linking individuals to appropriate resources.³²⁾

To address these gaps, our intervention combined both relation-

al and technological components: (1) citizen-led, relationship-based community support—including care planning, frailty education, and social participation activities—and (2) AI-enabled continuous monitoring with responsive feedback. This hybrid intervention mitigates structural limitations by promoting social participation and the timely identification of health outcomes.

Our research question posits that this citizen-led intervention can improve the health of older adults living in depopulated and aging rural communities. We hypothesize that participation will result in significant changes in depressive symptoms and frailty. By addressing critical gaps in both relational and technological support, this study aims to offer empirical evidence for scalable, community-driven intervention in healthcare in rural areas.

MATERIALS AND METHODS

Study Design, Setting, and Sampling

This study employed a single-arm pre-post quasi-experimental design to examine changes associated with citizen-participatory care interventions on community-dwelling older adults in Jeongup City, a rural depopulation area in Korea.

Inclusion criteria were age ≥ 65 years and residence in the study region. Participants were classified as dropouts if they missed the frailty prevention education program more than three times or failed to respond to more than seven of the 13 artificial intelligence (AI)-assisted check-in calls. Participants who did not complete the post-test survey were also considered dropouts. To minimize attrition, participants received a gift certificate worth 5,000 Korean won (KRW) at consent and after completing the intervention.

Of the 278 individuals initially expressing interest, 272 consented to participate. After applying the dropout criteria, 238 remained (12.5% dropout). After excluding incomplete survey responses, 206 were included in the final analysis (Fig. 1). Of the 28 dropouts, all had baseline demographic information; eight lacked baseline depressive symptoms or frailty scores and were excluded from attrition comparisons. Attrition analysis compared the final sample ($n = 206$) with excluded participants with sufficient baseline data ($n = 20$).

Providers of the Citizen-Led Intervention: Recruitment and Training Process

In this study, we developed a program led by trained citizens, referred to as Village Care Managers. Eligibility required only residency within the city; no additional qualifications were required. Candidates underwent screening through document review and interviews, and 16 Village Care Managers were recruited. Each manager was assigned to one district area (myeon or eup). The

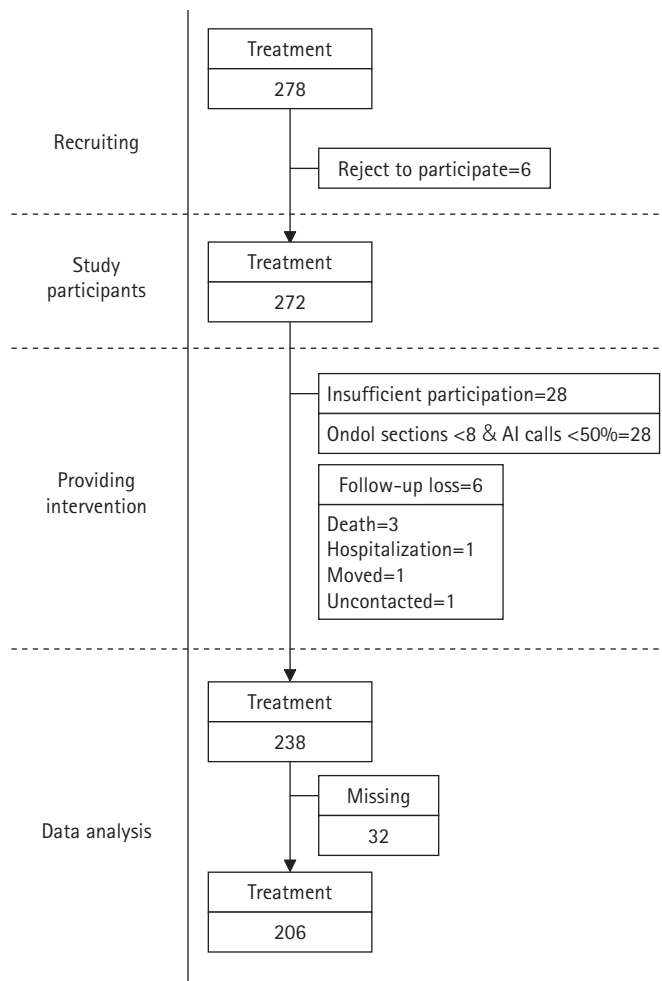


Fig. 1. Flow chart of the study.

training curriculum covered care for older adults, communication skills, windshield surveys to assess the community environment, characteristics of local public and welfare services, and use of the Care-Net platform.³⁴⁾ Managers participated in training sessions twice per month for 8 months.³⁵⁾

Intervention

The intervention was a 12-week program (April–June 2024) comprising four components: care planning and management, frailty prevention education, activities, and AI-assisted check-in calls with monitoring. Sessions took place in accessible, safe locations within senior centers or occasionally at a participant's home.

Care planning and management

Village Care Managers developed individualized care plans before the intervention, assessing each participant's health status, primary concerns, and care needs, and documenting weekly updates, in-

cluding participant-shared information. Assessment covered health conditions, functional status, and socioeconomic circumstances, with managers describing participants' commonly expressed health issues and current socioeconomic situation. They identified the top three priority health problems and determined whether linkage to public health or social welfare services was necessary, recording referral plans or specifying direct support.

During visits, managers logged the support provided—activity assistance, emotional support, social connectedness enhancement, or service linkage—along with notable observations, follow-up plans, and relevant photos or audio files.

Frailty prevention education program

This program included 12 weekly sections covering frailty prevention, cognitive activities, chronic disease management (e.g., hypertension, diabetes), nutrition, and muscle-strengthening exercises, each lasting 40 minutes and held once per week. Participants received a muscle-strengthening exercise poster and daily checklists to track their exercise performance. Care managers also provided additional exercise tools (e.g., grip balls, resistance bands) and encouraged participants to exercise regularly using the poster and checklist.

Various activities utilizing the care manager's capabilities

Village Care Managers leveraged their strengths to promote social involvement and community capacity, planning activities aligned with their skills, such as crafts, traditional games, Nanta performances, singing, drawing, and Korean-language lessons. These independently organized activities created opportunities for older adults to gather, interact, and participate in meaningful community life, enhancing both social connectedness and engagement within the community.

AI check-in calls and monitoring

The intervention included an AI-assisted check-in call system that placed automated voice calls to participants once or twice daily. The AI algorithm analyzed responses, identifying non-responses, silence, or predefined keywords indicating potential health or emotional concerns. Care managers reviewed call responses and followed up when participants required additional support, following the research team's monitoring protocol.³⁶⁾ To maximize responses, calls were scheduled when participants were likely to be available, with two additional attempts at 1-hour intervals if unanswered.

Measures

Outcome variables were measured at two points: before and after

the intervention. Both pre- and post-intervention surveys were conducted by trained data collectors.

Frailty

Frailty was assessed using the Korean Frailty Index (KFI),³⁷⁾ which includes eight dichotomous items: hospitalization (> 1 time in the past year), current health condition, polypharmacy (≥ 4 medications), unintentional weight loss, incontinence in the past month, Timed Up & Go performance (≥ 10 seconds), and difficulty with activities due to hearing or vision problems. Scores range from 0 to 8, with higher scores indicating greater frailty. Participants were classified as robust (KFI ≤ 2), prefrailty (KFI 3–4), or frailty (KFI ≥ 5) based on KFI cutoff scores.³⁷⁾

Depressive symptoms

Depressive symptoms were measured using the Korean version of the Geriatric Depression Screening Scale-Short Form (K-GDS-SF, 5 items).³⁸⁾ Items were scored 0 for "yes" and 1 for "no," with total scores ranging from 0 to 5. Scores greater than 2 indicated the presence of depressive symptoms based on the K-GDS-SF cutoff.

Statistical Analysis

Baseline demographic characteristics were described using independent t-tests and chi-square tests. To evaluate the intervention's outcomes over time, we conducted mixed-effects linear regression analyses with a random intercept for each participant. This approach assessed the main effects of time (pre- vs. post-intervention) and interaction effects (e.g., baseline frailty $\times$ time, baseline depression $\times$ time) on outcomes. All analyses were performed using Stata SE version 19.5 (StataCorp, College Station, TX, USA).

Ethical Considerations

This study was approved by the Institutional Review Board of Chung-Ang University (No. 1041078-20230426-HR-118).

RESULTS

Baseline Demographic Characteristics of Participants

Table 1 presents the baseline demographic characteristics of participants, stratified by depressive symptoms and frailty status. Of the 206 participants, 86 were classified as having depressive symptoms. Participants with depressive symptoms were older than those without depressive symptoms ($t = -2.98$, $p = 0.03$). Most were female ($\chi^2 = 4.46$, $p = 0.035$), lived alone ($\chi^2 = 9.96$, $p = 0.002$), and had more chronic diseases ($t = -2.09$, $p = 0.04$). Regarding frailty, 52 participants were classified as prefrail and 15 as frail. Participants in the frailty and prefrail groups were older

than those in the robust group ($F = 12.04$, $p < 0.001$). More than 90% of individuals in these groups were female ($\chi^2 = 11.09$, $p = 0.004$), lived alone ($\chi^2 = 13.42$, $p = 0.001$), and had a higher number of chronic diseases ($F = 15.06$, $p < 0.001$). Economic status was higher in the frailty group compared with the other groups ($\chi^2 = 17.43$, $p = 0.002$).

Attrition analysis showed no significant differences between the retained group ($n = 206$) and dropouts ($n = 20$) in demographic characteristics or baseline frailty. However, baseline depressive symptoms differed significantly ($p = 0.019$), with more dropouts classified as not depressed compared with the retained group (85% vs. 58.25%) (Supplementary Table S1).

Changes in Depression and Frailty over Time

Table 2 presents the changes in depressive symptoms over time according to frailty status. One-way ANOVA showed that before the intervention, depressive symptom scores differed significantly across the frailty groups ($F = 16.34$, $p < 0.001$), with the highest scores in the frailty group, followed by the prefrail and robust groups. After the intervention, differences among the groups remained significant ($F = 3.75$, $p = 0.025$), although post-hoc tests were not statistically significant. Post-pre difference analysis showed that the frailty group (-1.27 ± 1.49) decreased in depressive symptom scores compared with the other groups (robust 0.19 ± 2.38 , prefrail -0.13 ± 2.82), but the group difference was not statistically significant ($F = 2.52$, $p = 0.083$).

To describe changes in frailty scores according to depressive symptoms, independent t-tests were conducted (Table 3). Before the interventions, frailty scores differed significantly between not-depressed and depressed groups ($t = -6.50$, $p < 0.01$). After the intervention, a significant difference remained ($t = -3.20$, $p = 0.002$). Post-pre analysis showed that the not-depressed group (0.68 ± 1.61) had an increase in frailty scores compared with the depressed group (0.07 ± 1.77), and this difference was statistically significant ($t = 2.59$, $p = 0.01$).

Intervention Outcomes on Depressive Symptoms over Time according to Frailty Status

Mixed-effects linear regression results are presented in Table 4. In Model 1, frailty status corresponded to higher depressive symptoms scores compared with the robust group ($\beta = 1.25$, $p = 0.004$). However, depressive symptoms did not change significantly over time ($\beta = 0$, $p = 0.977$). In Model 2, which included the frailty $\times$ time interaction, the interaction term was statistically significant ($\beta = -1.461$, $p = 0.027$), reflecting that the pattern of change over time differed according to frailty status. Fig. 2A illustrates this interaction: the frailty group exhibited a decrease in depressive

Table 1. Baseline demographic characteristics of participants according to depression and frailty status

Characteristic	Total (n = 206)	Depressive symptoms				Frailty		
		Not depressed (n = 120)	Depressed (n = 86)	t or χ^2 (p-value)	Robust (n = 139)	Prefrail (n = 52)	Frail (n = 15)	F or χ^2 (p-value)
Age (y)	77.48 ± 6.01	76.44 ± 5.90	78.93 ± 5.90	-2.98 (0.003*)	76.37 ± 5.93	78.71 ± 5.29	83.47 ± 4.97	12.04 (< 0.001*)
65–74	63 (30.58)	44 (36.67)	19 (20.9)	5.34 (0.07)	52 (37.41)	10 (19.23)	1 (6.67)	14.96 (0.005*)
75–84	118 (57.28)	64 (53.33)	54 (62.79)		74 (53.24)	35 (67.31)	9 (60)	
≥ 85	25 (12.14)	12 (10)	13 (15.12)		13 (9.35)	7 (13.46)	5 (33.33)	
Sex								
Male	35 (16.99)	26 (21.67)	9 (10.47)	4.46 (0.035*)	32 (23.02)	2 (3.85)	1 (6.67)	11.09 (0.004*)
Female	171 (83.01)	94 (78.33)	77 (89.53)		107 (76.98)	50 (96.15)	14 (93.33)	
Family structure								
Living alone	105 (50.97)	50 (41.67)	55 (63.95)	9.96 (0.002*)	59 (42.45)	34 (65.38)	12 (80)	13.42 (0.001*)
Living with other(s)	101 (49.03)	70 (58.33)	31 (36.05)		80 (57.55)	18 (65.38)	3 (20)	
The number of chronic diseases	2.19 ± 1.32	2.03 ± 1.26	2.42 ± 1.37	-2.09 (0.04*)	1.91 ± 1.17	2.58 ± 1.26	3.53 ± 1.68	15.06 (< 0.001*)
Economic status (KRW)								
< 500,000	169 (82.04)	99 (82.5)	70 (81.4)	3.90 (0.14)	114 (82.01)	46 (88.46)	9 (60)	17.43 (0.002*)
500,000–999,999	21 (10.19)	9 (7.5)	12 (13.95)		12 (8.63)	3 (5.77)	4 (40)	
> 1,000,000	16 (7.77)	12 (10)	4 (4.65)		13 (9.35)	3 (5.77)	0 (0)	
Period of residence (y)	63.52 ± 21.48	61.4 ± 22.59	66.42 ± 19.55	-1.66 (0.1)	62.5 ± 22.77	64.21 ± 19.12	74.4 ± 12.52	2.31 (0.102)

Values are presented as mean±standard deviation or number (%).
*p<0.05.

Table 2. Changes in depressive symptoms scores before and after intervention according to frailty status (n=206)

Frailty group	Pre			Post			Post-pre		
	Mean ± SD	F	p-value	Mean ± SD	F	p-value	Mean ± SD	F	p-value
Robust (n = 139)	1.17 ± 1.82	16.34	< 0.001*	1.36 ± 1.95	3.75	0.025*	0.19 ± 2.38	2.52	0.083
Prefrail (n = 52)	2.10 ± 2.11			1.96 ± 2.21			-0.13 ± 2.82		
Frail (n = 15)	3.87 ± 1.64			2.6 ± 1.50			-1.27 ± 1.49		

Post hoc: Bonferroni.
*p<0.05.

Table 3. Changes in frailty scores before and after intervention according to depressive symptoms status (n=206)

Depressive symptoms group	Pre			Post			Post-pre		
	Mean ± SD	F	p-value	Mean ± SD	F	p-value	Mean ± SD	F	p-value
Not depressed (n = 120)	1.43 ± 1.25	-6.50	< 0.001*	2.12 ± 1.63	-3.20	0.002*	0.68 ± 1.61	2.59	0.01*
Depressed (n = 86)	2.77 ± 1.70			2.84 ± 1.55			0.07 ± 1.77		

*p<0.05.

Table 4. Mixed-effects linear regression models predicting depressive symptoms

Variable	Model 1		Model 2 (Frailty $\times$ Time)	
	β (robust SE)	p-value	β (robust SE)	p-value
Age	0.05 (0.02)	0.019*	0.051 (0.02)	0.019*
Sex (Ref. male)	0.54 (0.24)	0.022*	0.541 (0.28)	0.057
Income (Ref. < 500,000 KRW)				
500,000–999,999	0.53 (0.33)	0.106	0.529 (0.35)	0.127
> 1,000,000	0.13 (0.34)	0.706	0.129 (0.39)	0.744
Living alone (Ref. living with other)	0.23 (0.25)	0.357	0.226 (0.23)	0.324
Num of chronic disease	-0.03 (0.08)	0.723	-0.03 (0.08)	0.723
Period of residence	0.01 (0.01)	0.198	0.007 (0.01)	0.237
Frailty (Ref. robust)				
Prefrail	0.52 (0.28)	0.062	0.682 (0.31)	0.03*
Frail	1.25 (0.43)	0.004*	1.98 (0.55)	< 0.001*
Time (Ref. pre-time)	0 (0.17)	0.977	0.194 (0.21)	0.347
Prefrail $\times$ Time	-		-0.329 (0.4)	0.406
Frail $\times$ Time	-		-1.461 (0.66)	0.027*
Constant	-3.55 (1.5)	0.018*	-3.645 (1.52)	0.017*
Model fit	Wald $\chi^2(8) = 91.16$ p < 0.001 Log pseudolikelihood = -838.36 AIC = 1707.76 BIC = 1760.03 ICC = 0.133 (95% CI 0.039–0.367)		Wald $\chi^2(15) = 63.79$ p < 0.001 Log pseudolikelihood = -838.36 AIC = 1706.71 BIC = 1767.03; ICC = 0.145 (95% CI 0.054–0.333)	

SE, standard error; KRW, Korean won; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; ICC, intraclass correlation coefficient; CI, confidence interval.

Model 1: main effects only; Model 2: includes interaction between baseline frailty and time.

*p < 0.05.

symptoms over time, whereas the robust group showed a slightly increased pattern.

Model fit improved in Model 2 compared with Model 1 (Akaike Information Criterion [AIC] 1706.71 vs. 1707.76; Bayesian Information Criterion [BIC] 1767.03 vs. 1767.03). The intraclass correlation coefficient (ICC) was 0.145 (95% confidence interval [CI] 0.054–0.333), supporting the appropriateness of the mixed-effects approach.

Intervention Outcomes on Frailty over Time according to Depressive Symptoms Status

Using mixed-effects linear regression, we described frailty scores patterns over time according to depressive symptoms status (Table 5). In Model 3, the depressive symptoms group had higher frailty scores ($\beta = 0.59$, $p < 0.001$) and displayed a positive time-related change ($\beta = 0.43$, $p < 0.001$). In Model 4, which included the depressive symptoms $\times$ time interaction, the depressive symptoms group appeared to show decline in frailty scores over time ($\beta = -0.61$, $p = 0.011$). Fig. 2B illustrates these changes: frailty increased

in the not-depressed symptoms group, whereas the depressed symptoms group showed relative stable levels over time.

Model fit improved with the interaction term (AIC 1409.24 vs. 1413.91; BIC 1461.51 vs. 1462.16). The ICC for Model 4 was 0.186 (95% CI 0.092–0.341), indicating meaningful between-individual variability.

DISCUSSION

This study demonstrated the critical role of citizen participation in community-based care in rural areas. This citizen-led intervention was associated with observed reduction in depressive symptoms among participants in the frailty group and with a more gradual pattern of frailty change among those in the depressive symptoms group. Prior studies have shown that frailty and depression have dynamic, bidirectional relationships, with each condition potentially reinforcing the other and requiring targeted approaches.^{11,39,40} Consistent with this literature, our findings showed bidirectional patterns: participants with more severe baseline frailty or

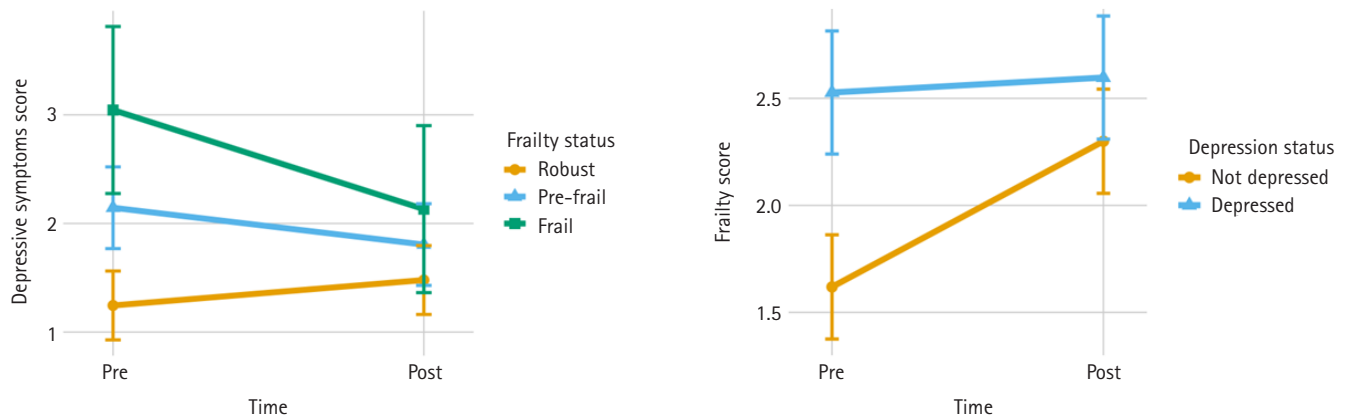


Fig. 2. Changes in depression and frailty over time by baseline status: (A) depressive symptoms scores by frailty status and (B) frailty scores by depressive symptoms status.

Table 5. Mixed-effects linear regression models predicting frailty

Variable	Model 1		Model 2 (Frailty × Time)	
	β (robust SE)	p-value	β (robust SE)	p-value
Age	0.07 (0.02)	< 0.001*	0.07 (0.02)	< 0.001*
Sex (Ref. male)	0.96 (0.21)	< 0.001*	0.96 (0.21)	< 0.001*
Income (Ref. < 500,000 KRW)				
500,000–999,999	0.44 (0.28)	0.116	0.44 (0.28)	0.116
> 1,000,000	-0.18 (0.32)	0.572	-0.18 (0.32)	0.572
Living alone (Ref. living with others)	0 (0.17)		0 (0.17)	0.998
Num of chronic disease	0.3 (0.06)	< 0.001*	0.30 (0.06)	< 0.001*
Period of residence	0 (0)	0.947	0 (0)	0.947
Depressive symptoms (Ref. not depressed)	0.59 (0.15)	< 0.001*	0.89 (0.19)	< 0.001*
Time (Ref. pre-time)	0.43 (0.12)	< 0.001*	0.68 (0.15)	< 0.001*
Depressive symptoms × Time			-0.61 (0.24)	0.011*
Constant	-5.36 (1.03)	< 0.001*	-5.48 (1.03)	< 0.001*
Model fit	Wald $\chi^2(8) = 257.78$ p < 0.001 Log pseudolikelihood = -694.952 AIC = 1413.91; BIC = 1462.16; ICC = 0.171 (95% CI 0.077–0.336)		Wald $\chi^2(10) = 262.43$ p < 0.001 Log pseudolikelihood = -691.62 AIC = 1409.24 BIC = 1461.51 ICC = 0.186 (95% CI 0.092–0.341)	

SE, standard deviation; KRW, Korean won; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; ICC, intraclass correlation coefficient; CI, confidence interval.

Model 3: main effects only; Model 4: includes interaction between baseline depressive symptoms and time.

*p < 0.05.

depressive symptoms appeared to exhibit relatively greater short-term changes during the 12-week program, suggesting that individuals with higher vulnerability may show more noticeable changes, even in brief intervention. However, although improvements in frailty and depressive symptoms were observed, these changes cannot be interpreted as causal effects due to the absence of a control group. Thus, the findings should be viewed as explor-

atory indications of potential short-term changes associated with participation in citizen-led care activities. To further interpret these exploratory findings, it is important to situate them within the broader literature on rural aging and community-based care.

Previous studies on interventions for older adults in rural areas have primarily focused on health status or healthcare services, without adequately considering the unique environmental charac-

teristics of rural settings.⁴¹⁾ Yet, in rural contexts, older adult care requires not only formal care services but also strong social relationships that help connect and complement these services.⁴²⁾ Study on the role of citizens who deliver food or groceries to older adults in rural areas has shown that, through meal delivery, citizens not only strengthened social relationships with older adults but also monitored their nutritional and emotional well-being, effectively acting as informal care providers. In doing so, they helped fill gaps left by the formal social service system.⁴³⁾ These prior studies help explain why citizen-led participation may influence older adults' well-being, particularly in rural areas where formal care resources are limited.

Village Care Managers, who lived in the same rural communities as participants, brought contextual knowledge and cultural familiarity that enabled them to provide personalized support and build trusting relationships with older adults. This finding aligns with the social determinants of health perspective, illustrating how mobilizing social capital into formal care governance can improve health outcomes in resource-constrained settings.^{44,45)} Through management, ongoing monitoring, and education, participants received tailored support that encouraged health literacy, regular physical activity,⁴⁶⁾ and community engagement.⁴⁷⁾ The AI-assisted check-in calls were also perceived as signs of care and concern and enabled interaction and monitoring even when managers were not present. These elements likely contributed to short-term changes among participants with greater vulnerability—such as those with more severe baseline frailty or depressive symptoms—although these patterns are observational rather than causal.

Citizen participation in this intervention moved beyond tokenistic engagement. Village Care Managers were not positioned merely as informants or volunteers but as active agents who delivered care, monitored health needs through AI-assisted check-in calls, and built trust-based relationships with older adults. Such engagement demonstrates how meaningful community participation can contribute to the implementation of care activities in ways that are responsive to local needs.⁴⁸⁾ By granting citizens an operational role within the care governance structure, this study demonstrates a feasible pathway to address workforce shortages in depopulated rural areas and to support more contextually responsive and sustainable care provision.^{23,44)}

Citizen involvement throughout the preparation and implementation process supported ownership and continuity.⁴⁹⁾ Their participation helped ensure clarity of roles and strengthened engagement during the intervention. Building on this foundation, ensuring ongoing education and structured support will be important for maintaining consistency and quality in future community-led care approaches.^{20,50)} Future research should explore how citi-

zen-led interventions can be supported and adapted across diverse rural settings, particularly in areas with severe workforce constraints.

Our study showed that Village Care Managers delivered activities aligned with their individual strengths. In addition to these activities, regular training sessions on core components—such as frailty education and AI check-in call monitoring—helped maintain consistency across the intervention. In this way, the program balanced local adaptability with fidelity to essential components, supporting both flexibility and implementation feasibility.

In the attribution analysis, dropout participants showed lower baseline depressive symptoms than those retained in the final analysis. Although this suggests that individuals with better baseline mental health were more likely to discontinue the program, no differences emerged in other demographic or health characteristics. Thus, while some attrition-related selections cannot be entirely excluded, their impact on internal validity appears limited.

This study has several limitations. Conducted in a single region with a small sample, generalizability is limited. In addition, the study did not employ a randomized controlled trial (RCT) design, making it difficult to estimate the intervention's effect size or rule out potential confounders such as maturation or historical influencers. To partially address this, we used mixed-effects regression to account for time-related changes and individual heterogeneity. A key strength of this study, despite the challenges of community-based implementation, is the repeated measurement of frailty and depression, which enabled a close examination of longitudinal change. Further RCTs with flexible protocols balancing standardization and regional adaptation are needed to strengthen internal validity.

The short intervention period also limited our ability to assess long-term effectiveness, particularly for chronic conditions. Extended follow-up studies are needed to evaluate sustainability and cumulative effects. Because of possible ceiling effects, frailty scores in the depressive symptoms group may have shown a more gradual trajectory than those in the non-depressive symptoms group. Future research should incorporate more sensitive frailty measures, such as the Short Physical Performance Battery or grip strength, to capture subtle changes.

Finally, given the limited evidence on the bidirectional relationship between frailty and depression among older adults in Korea, qualitative studies—including in-depth interviews—will be important for clarifying contextual mechanisms in rural settings and refining care strategies.

In conclusion, this study highlights how citizen care providers may contribute to addressing care needs in rural depopulation areas, where shortages in care infrastructure and workforce remain

persistent. Participants who engaged in citizen-led care interventions showed short-term decreases in depressive symptoms and frailty scores. These patterns indicate the possibility of meaningful short-term changes among vulnerable older adults. However, controlled studies are required to confirm whether these preliminary observations represent intervention effects.

To further develop this intervention, it is necessary to provide systematic education and capacity-building programs, as well as sustained financial and institutional support, to enhance the sustainability and scalability of citizen-led care in super-aged rural communities. Further research should examine long-term patterns and assess implementation approaches across diverse rural settings to validate the intervention's applicability and impact.

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CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Conceptualization, SSP, SNJ; Data curation, SHC, EHC, MKK; Funding acquisition, SNJ; Investigation, SHC, EHC, JHC, MKK, SKK, SYP; Methodology, SSP, SNJ, SHC, EHC, JHC, MKK; Project administration, SNJ; Supervision, SNJ; Visualization, SHC, SSP; Writing-original draft, SHC; Writing-review & editing, SNJ.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via <https://doi.org/10.4235/agmr.25.0177>.

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