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Retrospective observational study of the association between changes in physical activity and frailty in middle-aged and older adults: evidence from the Korean Longitudinal Study of Aging (2006–2022)

Ye Jun Jung,[1] Junhyuk Kim,[1] Yun Seo Jang ,[2] Eun-Cheol Park [2,3]

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YJJ and JK contributed equally.

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For numbered affiliations see end of article.

Correspondence to
Prof Eun-Cheol Park; ecpark@yuhs.ac and Ms Yun Seo Jang; 0112ysj@yuhs.ac

ABSTRACT

Objectives This study aimed to investigate the relationship between changes in physical activity and frailty among middle-aged and older adults in Korea, using panel data from the 2006–2022 Korean Longitudinal Study of Aging (KLoSA).

Design Retrospective observational study.

Setting For this longitudinal panel study, data were sourced from the KLoSA dataset.

Participants We analysed data from 5594 participants (2855 males and 2739 females) extracted from KLoSA data collected between 2006 and 2022.

Primary and secondary outcome measures The frailty index was calculated based on 6 clinical domains comprising 34 age-related health deficits. Changes in physical activity were categorised as persistently inactive, decreased, increased or persistently active. Logistic regression analysis using generalised estimating equations was conducted to assess the association between changes in physical activity and frailty.

Results The persistently active group (OR=0.45, 95% CI: 0.40 to 0.50) showed a lower likelihood of frailty than did the persistently inactive group. In the group that increased their physical activity, the OR was 0.57 (95% CI: 0.52 to 0.63), and higher ORs were observed for current smokers and those residing in rural areas.

Conclusions This study demonstrated that persistent and increased physical activity is associated with lower frailty in middle-aged and older adults in Korea. Therefore, participation in physical activity in the older adults is one of the important ways to prevent frailty.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Used a comprehensive longitudinal dataset from the Korean Longitudinal Study of Aging spanning 16 years, allowing for robust temporal analysis.
- ⇒ Employed a large sample size of 5594 participants, enhancing the generalisability of the findings to the middle-aged and older Korean population.
- ⇒ Applied a frailty index based on 34 age-related health deficits, providing a detailed and multidimensional assessment of frailty.
- ⇒ The observational study design limits the ability to establish causal relationships between changes in physical activity and frailty, and data collection relied on self-reported measures of physical activity, which may be subject to recall bias and social desirability bias.
- ⇒ Findings provide critical evidence to inform public health interventions and frailty prevention strategies in Korea, emphasising the need for targeted healthcare approaches, particularly in underserved rural areas.

INTRODUCTION

The demographic shift towards an ageing population is a growing concern in South Korea. In 2023, the proportion of those aged ≥65 years in the South Korean population was a staggering 18.2%,[1] with declining birth rates and longer life expectancies primarily contributing to the country's rapidly ageing society. It is predicted that 47.7% of the total population will be aged ≥65 years by 2072,[1] which will undoubtedly result in a greater societal burden owing to the comorbidities associated with advanced age.

As individuals age, they face various vulnerabilities, with frailty emerging as a significant health concern.[2] Frailty, measured through the frailty index (FI), is defined by an increased susceptibility to adverse events, leading to a decline in both physical and cognitive functions.[2] FI is calculated using the following variables: self-rated health, physical condition, mental status, activities of daily living (ADL), instrumental activities of daily living (IADL) and chronic conditions. Research has shown that as the population ages, frailty becomes more prevalent,[3 4] suggesting that a higher FI may heighten the risk of negative health outcomes. Consequently, there is a pressing need for research into factors that can positively impact FI among middle-aged and older adults in South Korea.

While numerous factors may affect frailty, recent studies have highlighted the prevalence of frailty among older adults with low levels of physical activity and increased sedentary behaviours.[5 6] Regular physical activity is widely acknowledged to improve the mental and physical health of older adults,[7] contributing significantly to functional autonomy[8] and the reversal of some detrimental effects of chronic illnesses.[7] However, the widespread use of technology has decreased physical activity levels among older adults.[5] For example, a study on physical activity in Korea[9] found that 66.8% of older adults did not engage in sufficient levels of physical activity, compared with 53.9% of young adults in 2020.[9] This implies that inadequate physical activity increases the risk of adverse health effects and frailty among older adults. Similarly, another study assessing prefrailty factors in middle-aged and older Australian adults aged 40–75 years suggests that interventions to prevent frailty progression, such as initiatives to enhance physical activity, should be initiated as early as the fourth decade of life.[10]

Building upon this prior work,[9 10] we sought to investigate the effect of modifying physical activity levels on the FI of middle-aged and older adults in South Korea. Specifically, we analysed changes in physical activity through a longitudinal study, contrasting with previous cross-sectional studies. Additionally, the frequency and duration of exercise were assessed to determine the recommended level of physical activity for preventing frailty.

This study aimed to investigate the association between changes in physical activity and frailty among middle-aged and older adults in Korea, using panel data from the 2006–2022 Korean Longitudinal Study of Aging (KLoSA). We hypothesised that increasing physical activity levels would be associated with a decreased risk of frailty owing to the previously described beneficial health outcomes associated with regular physical activity.

METHODS

Data and participants

This study used panel data from KLoSA, a nationally representative longitudinal study focusing on Koreans aged ≥45 years. KLoSA has been conducted biennially since 2006 by the Korean Labor Institute and collects demographic, socioeconomic and health-related data from participants randomly selected through a multistage stratified sampling method. These data primarily inform the development of social and economic policies to address the challenges associated with the rapidly ageing population in Korea.[11]

For this longitudinal panel study, data were sourced from the 2006–2022 KLoSA dataset, encompassing participants who completed all nine waves (waves 1–9). Study participants included middle-aged and older adults (aged ≥45 years) living in South Korea. In total, 13 661 individuals were enrolled between 2006 (wave 1; baseline year) and 2022 (wave 9). Among these enrollees, those newly added to the 2014 panel data (n=4158) were excluded, along with individuals with missing data on various demographic and health-related variables, such as sex, age, region, marital status, educational level, employment status, income level, smoking status, alcohol consumption or participation in social activities (n=1503). Additionally, individuals who were classified as frail (FI≥0.25) in the first wave (n=962) were excluded to ensure our analysis focused on comparing changes in physical activity across different periods rather than including data from the baseline year itself. Finally, we excluded those who did not follow up or died by 2022 among the participants (n=1444). Ultimately, the final study population comprised 5594 participants, including 2855 males and 2739 females. Figure 1 depicts a flowchart illustrating the participant selection process from 2006 to 2022.

Variables

The dependent variable, FI, was used to assess health deficits across six clinical domains (self-rated health, physical condition, mental status, ADL, IADL and chronic conditions) consisting of 34 age-related health deficits. The domains were composed of the following: self-rated health (1 item: self-rating of health), physical condition (7 items: impaired vision, impaired hearing, sleep disturbance, weight loss, limitation in usual activities due to health problem, body mass index, grip strength), mental status (4 items: I had trouble keeping my mind on what I was doing, I felt everything I did was an effort, I felt lonely, I could not get 'going'), ADL (4 items: help dressing, personal hygiene, bathing and getting in/out of bed), IADL (10 items: help grooming, housework, meal preparations, laundry, walking around house, using transportation, shopping, finances, phone use, taking medication) and chronic conditions (8 items: hypertension, diabetes, chronic lung disease, heart disease, stroke, arthritis, urinary incontinence, regularly prescribed medications). The distribution of participants by items is presented in online supplemental file 1. The FI for each participant was calculated by dividing the number of deficits by the total sum of potential health deficits. Participants were classified as frail if the FI was ≥0.25 and non-frail if it was <0.25.[12 13]

Physical activity was assessed by asking participants if they regularly engaged in any exercise at least once a week. Responses to this binary question were used to classify the variable of interest (changes in physical activity) into distinct groups. Those who responded 'no' were coded as 0 and 'yes' as 1. Changes in physical activity were categorised using the 'LAG' function in SAS into the following four groups: persistently inactive (0–0), decreased activity (1–0), increased activity (0–1) and persistently active (1–1).

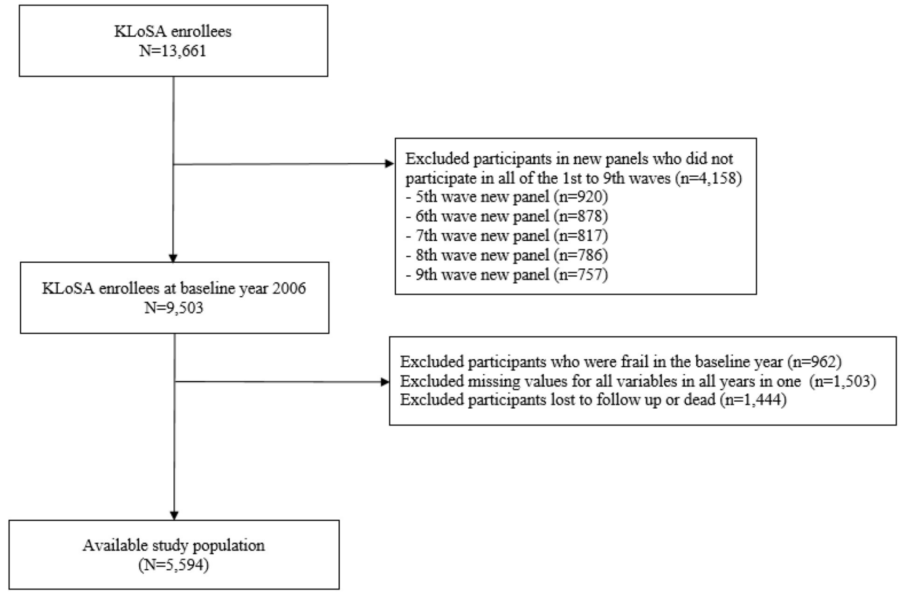

Figure 1 Flowchart of selection of study participants from 2006 to 2022 according to inclusion and exclusion criteria. KLoSA, Korean Longitudinal Study of Aging.

Covariates included sociodemographic factors and other factors affecting frailty.[14] Sociodemographic factors comprised sex (male or female), age (45–54, 55–64, 65–74, 75–84 or ≥85 years), region (metropolitan, urban or rural), marital status (married or unmarried), educational level (middle school or below, high school, university or higher), employment status (employed or unemployed), income level (quantile 1, 2 or 3) and participation in social activities (yes or no). Other covariates included smoking status (non-smoker, ex-smoker or current smoker) and alcohol consumption (never, past or current).[14]

Statistical analyses

All statistical analyses were performed using SAS (V.9.4; SAS Institute, Inc., Cary, NC, USA). χ^2 tests were performed to compare baseline characteristics of the study population based on frailty status. Logistic regression analysis with generalised estimating equations (GEEs) was employed to analyse repeated measures of binary outcomes and calculate ORs with 95% CIs. This analysis allowed us to examine the association between changes in physical activity and the frailty status of the study participants while adjusting for covariates. Subgroup analysis stratified by independent variables was conducted to show association between changes in physical activity and frailty. It means that, for instance, conducting subgroup analysis stratified by sex is one for males only, and one for females only, each adjusting for all other covariates excluding sex. Finally, we performed an additional analysis by categorising each frailty index divided into six clinical domains in detail. This allowed us to conduct a more granular assessment of the individual issues.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research. The data included only survey participants who could not be identified by public data.

RESULTS

Table 1 outlines the baseline characteristics of the study population (2006–2008). Of the 5594 participants, 5140 were classified as non-frail (FI<0.25) and 454 met the criteria for frailty (FI≥0.25). Among those with decreased physical activity (n=836), 88.6% (n=741) were non-frail and 11.4% (n=95) were frail. Conversely, among the participants with increased physical activity (n=691), 93.5% (n=646) were non-frail and 6.5% (n=45) were frail. The persistently active group exhibited the lowest percentage of frailty, with only 4.0% (n=53) classified as frail and 96.0% (n=1284) as non-frail.

Table 2 displays the results of the GEE analysis of factors associated with the FI (2006–2022). All analyses were adjusted for covariates, with the persistently inactive group (0–0) serving as the reference. The OR for the decreased physical activity group was 0.92 (95% CI: 0.84 to 1.00). The OR decreased to 0.57 (95% CI: 0.52 to 0.63) in the increased physical activity group and was lowest for the persistently active group (1–1) (OR=0.45, 95% CI: 0.40 to 0.50). These findings suggest that increased physical activity is associated with a lower risk of frailty in middle-aged and older adults and vice versa.

Table 3 shows the results of subgroup analyses stratified by independent variables (sex, age, region, marital status, educational level, income level, smoking status and alcohol intake) (2006–2022). Both males and females in the persistently active group (1–1) exhibited the lowest

Table 1 Baseline characteristics of the study population (2006–2008)

Variables	Frailty						
	Total		Not frail		Frail		
	N	%	N	%	N	%	P value
Total	5594	100.0	5140	91.9	454	8.1	
Changes in physical activity							**<0.001**
Persistently inactive	2730	48.8	2469	48.0	261	57.5	
Decrease	836	14.9	741	14.4	95	20.9	
Increase	691	12.4	646	12.6	45	9.9	
Persistently active	1337	23.9	1284	25.0	53	11.7	
Sex							**<0.001**
Male	2855	51.0	2680	52.1	175	38.5	
Female	2739	49.0	2460	47.9	279	61.5	
Age (years)							**<0.001**
45–54	1376	24.6	1362	26.5	14	3.1	
55–64	1605	28.7	1556	30.3	49	10.8	
65–74	1765	31.6	1573	30.6	192	42.3	
75–84	729	13.0	569	11.1	160	35.2	
≥85	119	2.1	80	1.6	39	8.6	
Region							0.082
Metropolitan	2316	41.4	2142	41.7	174	38.3	
Urban	1760	31.5	1596	31.1	164	36.1	
Rural	1518	27.1	1402	27.3	116	25.6	
Marital status							**<0.001**
Married	4434	79.3	4166	81.1	268	59.0	
Unmarried	1160	20.7	974	18.9	186	41.0	
Educational level							**<0.001**
Middle school or below	3509	62.7	3135	61.0	374	82.4	
High school	1503	26.9	1437	28.0	66	14.5	
University or higher	582	10.4	568	11.1	14	3.1	
Employment status							**<0.001**
Employed	2799	50.0	2738	53.3	61	13.4	
Unemployed	2795	50.0	2402	46.7	393	86.6	
Income level							**<0.001**
Quantile 1 (low)	1597	28.5	1375	26.8	222	48.9	
Quantile 2	1871	33.4	1710	33.3	161	35.5	
Quantile 3 (high)	2126	38.0	2055	40.0	71	15.6	
Smoking status							**<0.001**
Non-smoker	3639	65.1	3316	64.5	323	71.1	
Ex-smoker	782	14.0	704	13.7	78	17.2	
Current smoker	1173	21.0	1120	21.8	53	11.7	
Alcohol intake							**<0.001**
Never	2696	48.2	2440	47.5	256	56.4	
Past	554	9.9	456	8.9	98	21.6	
Current	2344	41.9	2244	43.7	100	22.0	
Participation in social activities							**<0.001**
Yes	4419	79.0	4173	81.2	246	54.2	
No	1175	21.0	967	18.8	208	45.8	

Continued

Table 1 Continued

Variables	Frailty						
	Total		Not frail		Frail		
	N	%	N	%	N	%	P value

*Blod values statistically significant p-vaules.

OR for frailty (males: OR=0.46, 95% CI: 0.39 to 0.54; females: OR=0.44, 95% CI: 0.38 to 0.51). Increased physical activity was associated with reduced frailty risk across all subgroup analyses stratified by independent variables. In the persistently active group, individuals who were current smokers (OR=0.67, 95% CI: 0.46 to 0.96) and those residing in rural areas (OR=0.54, 95% CI: 0.42 to 0.70) exhibited the highest ORs for frailty for their respective subgroups. Notably, in the age category, the OR for frailty in the decreased physical activity group was substantially higher than that in the persistently inactive group (OR=1.00), particularly within the middle-aged categories of 45–54 years (decreased physical activity: OR=1.65, 95% CI: 0.81 to 3.36; persistently inactive: OR=1.00) and 55–64 years (decreased physical activity: OR=1.23, 95% CI: 0.96 to 1.57; persistently inactive: OR=1.00).

Table 4 presents the results of the subgroup analysis for six frailty index stratified by the dependent variables. All six clinical domains used to quantify the FI in this study—ADL, IADL, self-rated health condition, physical condition, mental status and chronic conditions—were examined. Self-rating of health was divided into good for those who answered excellent, or very good, and bad for fair or poor. For the other five domains, individual items were added for each domain, and the average value was calculated to subgroup with or without the average within the group. Regarding ADL and IADL, the OR for frailty was significantly lower in those with increased physical activity (ADL: OR=0.32, 95% CI: 0.26 to 0.40; IADL: OR=0.63, 95% CI: 0.57 to 0.69) than in those with decreased physical activity (ADL: OR=0.71, 95% CI: 0.61 to 0.84; IADL: OR=0.88, 95% CI: 0.81 to 0.96). Among individuals with chronic conditions, the OR for frailty was nearly identical between individuals who decreased (OR=1.09, 95% CI: 1.04 to 1.15) or increased their physical activity (OR=1.07, 95% CI: 1.02 to 1.13).

Figure 2 illustrates the results of the subgroup analysis stratified by frequency and duration of exercise. Compared with the reference group with an exercise frequency of 0 times/week or 0 min/session, the OR for frailty was 0.44 (95% CI: 0.35 to 0.56) among those who increased their physical activity over time and 0.49 (95% CI: 0.39 to 0.63) among those who were persistently active, that is, exercised 1–2 times/week. Similar ORs were observed when participants exercised >7 times/week, especially among those with increased physical activity (OR=0.49, 95% CI: 0.42 to 0.58). Regarding the exercise duration, the OR of frailty for those who exercised 1–30 min/session was 0.72 (95% CI: 0.62 to 0.82) in the group that increased physical activity and 0.68 (95% CI: 0.59 to 0.79) in the persistently active group; the OR for frailty decreased further to 0.53 (95% CI: 0.46 to 0.60) and 0.40 (95% CI: 0.35 to 0.45), respectively, in the group that exercised for 30–60 min/session. These findings highlight a substantial decrease in the OR for frailty as the duration of exercise increases from 1 to 30 min/session to 30–60 min/session.

DISCUSSION

Key findings

Our findings revealed an association between increased physical activity and lower FI, indicating a decreased risk of frailty among middle-aged and older adults. Notably, persistently active individuals (1–1) and those who increased their physical activity levels (0–1) exhibited lower susceptibility to frailty, with those engaging in increased physical activity (0–1) reporting lower frailty rates than those with decreased physical activity (1–0). These trends persisted across sexes and all age groups after adjusting for covariates. Among persistently active individuals, the OR for frailty remained consistent regardless of weekly exercise frequency, that is, whether they exercised 1–2 times/week or >7 times/week. However, exercise duration showed a pronounced effect, as the OR for frailty markedly decreased as the duration of each workout session increased. This finding suggests that exercise duration, rather than frequency, is closely correlated with frailty risk. Additionally, insights from the ORs indicate that engaging in exercise for at least 30 min/session, 1–2 times per week, is associated with a lower frailty risk in middle-aged and older adults.

Comparison with previous studies

Previous studies assessing the association between physical activity and frailty align with these findings.[6 15] In a previous cross-sectional study that examined the risk factors for frailty among community-dwelling older adults aged ≥60 years in Birjand, Iran, a robust positive association between low physical activity and frailty was reported.[6] Specifically, the FI of individuals with low physical activity levels was approximately 15.5 times higher than that of those with moderate-to-high physical activity levels.[6] Similarly, a Taiwanese study investigated the relationship between physical activity trajectory patterns and frailty in adults aged ≥60 years using longitudinal data. The study concluded that individuals who experienced a decline in physical activity exhibited the lowest frailty score, whereas those with increasing physical activity levels showed higher frailty scores. Furthermore, the persistently active group demonstrated a 63.3% lower susceptibility to

Table 2 Results of generalised estimating equation (GEE) analysis of factors associated with frailty (2006–2022)

	Frailty	
Variables	**OR**	**95% CI**
Changes in physical activity		
Persistently inactive	1.00	
Decrease	0.92	(0.84 to 1.00)
Increase	**0.57**	(0.52 to 0.63)
Persistently active	**0.45**	(0.40 to 0.50)
Sex		
Male	**1.33**	(1.15 to 1.55)
Female	1.00	
Age (years)		
45–54	1.00	
55–64	**1.94**	(1.45 to 2.59)
65–74	**3.57**	(2.64 to 4.81)
75–84	**6.70**	(4.95 to 9.08)
≥85	**12.39**	(9.03 to 16.99)
Region		
Metropolitan	1.00	
Urban	**1.14**	(1.02 to 1.27)
Rural	**0.88**	(0.78 to 0.99)
Marital status		
Married	1.00	
Unmarried	**1.46**	(1.32 to 1.62)
Educational level		
Middle school or below	**1.64**	(1.33 to 2.01)
High school	**1.30**	(1.04 to 1.62)
University or higher	1.00	
Employment status		
Employed	1.00	
Unemployed	**3.15**	(2.80 to 3.54)
Income level		
Quantile 1 (low)	1.03	(0.94 to 1.13)
Quantile 2	1.05	(0.96 to 1.14)
Quantile 3 (high)	1.00	
Smoking status		
Non-smoker	1.00	
Ex-smoker	**1.24**	(1.08 to 1.44)
Current smoker	0.87	(0.73 to 1.05)
Alcohol intake		
Never	1.00	
Past	**1.45**	(1.28 to 1.64)
Current	**0.57**	(0.50 to 0.66)
Participation in social activities		
Yes	1.00	
No	**1.94**	(1.81 to 2.08)

Bold values statistically significant p-vaules.

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Table 3 Results of subgroup analysis stratified by independent variables (2006–2022)

Variables	Changes in physical activity						
	Persistently inactive	Decrease		Increase		Persistently active	
	OR	OR	95% CI	OR	95% CI	OR	95% CI
Sex							
Male	1.00	1.01	(0.89 to 1.15)	**0.56**	(0.48 to 0.65)	**0.46**	(0.39 to 0.54)
Female	1.00	**0.86**	(0.77 to 0.96)	**0.59**	(0.52 to 0.67)	**0.44**	(0.38 to 0.51)
Age (years)							
45–54	1.00	1.65	(0.81 to 3.36)	0.76	(0.31 to 1.89)	0.41	(0.15 to 1.10)
55–64	1.00	1.23	(0.96 to 1.57)	**0.67**	(0.50 to 0.90)	**0.51**	(0.37 to 0.71)
65–74	1.00	0.88	(0.76 to 1.02)	**0.59**	(0.50 to 0.69)	**0.46**	(0.39 to 0.55)
75–84	1.00	0.94	(0.83 to 1.06)	**0.54**	(0.47 to 0.64)	**0.39**	(0.33 to 0.46)
≥85	1.00	**0.71**	(0.56 to 0.92)	**0.46**	(0.360.59)	**0.46**	(0.34 to 0.62)
Region							
Metropolitan	1.00	**0.83**	(0.73 to 0.95)	**0.52**	(0.45 to 0.60)	**0.41**	(0.35 to 0.48)
Urban	1.00	1.02	(0.89 to 1.17)	**0.61**	(0.52 to 0.73)	**0.46**	(0.38 to 0.55)
Rural	1.00	0.94	(0.78 to 1.13)	**0.59**	(0.47 to 0.72)	**0.54**	(0.42 to 0.70)
Marital status							
Married	1.00	0.98	(0.88 to 1.09)	**0.58**	(0.51 to 0.65)	**0.44**	(0.39 to 0.50)
Unmarried	1.00	**0.83**	(0.72 to 0.95)	**0.56**	(0.47 to 0.65)	**0.47**	(0.39 to 0.56)
Educational level							
Middle school or below	1.00	0.91	(0.82 to 1.00)	**0.58**	(0.52 to 0.65)	**0.45**	(0.39 to 0.51)
High school	1.00	0.94	(0.78 to 1.15)	**0.54**	(0.43 to 0.69)	**0.45**	(0.36 to 0.57)
University or higher	1.00	1.03	(0.66 to 1.62)	**0.54**	(0.32 to 0.91)	**0.42**	(0.27 to 0.67)
Income level							
Quantile 1 (low)	1.00	0.99	(0.87 to 1.13)	**0.53**	(0.46 to 0.63)	**0.45**	(0.38 to 0.53)
Quantile 2	1.00	0.93	(0.81 to 1.07)	**0.56**	(0.48 to 0.65)	**0.49**	(0.41 to 0.57)
Quantile 3 (high)	1.00	0.82	(0.68 to 1.00)	**0.56**	(0.45 to 0.71)	**0.32**	(0.25 to 0.41)
Smoking status							
Non-smoker	1.00	0.93	(0.84 to 1.03)	**0.59**	(0.52 to 0.66)	**0.46**	(0.40 to 0.52)
Ex-smoker	1.00	0.90	(0.75 to 1.09)	**0.49**	(0.40 to 0.61)	**0.42**	(0.33 to 0.52)
Current smoker	1.00	1.12	(0.85 to 1.46)	**0.61**	(0.41 to 0.89)	**0.67**	(0.46 to 0.96)
Alcohol intake							
Never	1.00	0.90	(0.80 to 1.00)	**0.62**	(0.54 to 0.70)	**0.46**	(0.40 to 0.54)
Past	1.00	0.97	(0.83 to 1.14)	**0.47**	(0.38 to 0.56)	**0.41**	(0.34 to 0.50)
Current	1.00	1.00	(0.82 to 1.24)	**0.62**	(0.48 to 0.78)	**0.50**	(0.39 to 0.64)

Bold values statistically significant p-vaules.

frailty than the persistently inactive reference group.[16] Consequently, the findings of these studies support the study hypothesis that increased physical activity is associated with a lower the risk of frailty in older adults. This study uniquely targeted middle-aged adults (45–64 years) and older adults (≥65 years), highlighting the relevance of physical activity for the prevention of frailty across multiple age groups. A notable finding was that middle-aged adults with decreased physical activity demonstrated heightened susceptibility to frailty compared with older adults, as indicated by ORs, despite not being statistically significant in the middle-aged category. Nevertheless, the association between increased physical activity and a lower risk of frailty was evident across all age groups, highlighting the benefits of regular physical activity as individuals age. Taken together, these results suggest that while regular physical activity is crucial for preventing frailty in older adults, it also plays a significant role in mitigating frailty in middle-aged adults. A prior study examined the association between lifestyle changes and

Table 4 Results of subgroup analysis stratified by dependent variables (2006–2022)

Variables	Changes in physical activity						
	Persistently inactive	Decrease		Increase		Persistently active	
	OR	OR	95% CI	OR	95% CI	OR	95% CI
ADL	1.00	**0.71**	(0.61 to 0.84)	**0.32**	(0.26 to 0.40)	**0.22**	(0.17 to 0.28)
IADL	1.00	**0.88**	(0.81 to 0.96)	**0.63**	(0.57 to 0.69)	**0.50**	(0.45 to 0.56)
Self-rating of health	1.00	**0.93**	(0.87 to 0.99)	**0.75**	(0.70 to 0.80)	**0.73**	(0.69 to 0.78)
Physical condition	1.00	0.98	(0.91 to 1.06)	**0.87**	(0.81 to 0.94)	**0.78**	(0.72 to 0.83)
Mental status	1.00	0.98	(0.92 to 1.04)	**0.84**	(0.79 to 0.89)	**0.70**	(0.66 to 0.75)
Chronic conditions	1.00	1.09	(1.04 to 1.15)	1.07	(1.02 to 1.13)	1.15	(1.08 to 1.22)

*Bold values statistically significant p-vaules.
ADL, activities of daily living; IADL, instrumental activities of daily living.

cognitive function among Koreans using longitudinal data.[15] Among various lifestyle factors, engaging in exercise for over 150 min/week was associated with advantageous effects on older adults' cognitive functioning,[15] measured using the Korean Mini-Mental State Examination (K-MMSE) scores. This implies that regular physical activity reduces the risk of frailty in older adults, as the FI assesses health status by evaluating deficits, including those related to cognitive function (K-MMSE). Although this study did not incorporate deficits related to this clinical domain (cognitive function) when calculating the FI, previous research[17 18] supports the notion that increased physical activity is associated with a decrease in FI, regardless of whether the K-MMSE values were included in the calculation.[18]

Mechanisms between physical activity and frailty

There are several plausible mechanisms linking changes in physical activity to frailty. First, physical activity significantly contributes to the mental and physical health of older adults.[7] Regular physical activity plays a crucial role in enhancing functional autonomy[8] and mitigating the adverse effects of various chronic illnesses.[7] Second, the association between changes in physical activity and frailty may be explained through sedentary behaviour. Decreased sedentary time resulting from increased participation in physical activities is often linked to reduced frailty levels.[5 19] A previous study suggests that fewer sedentary activities are associated with a lower risk of frailty,[19] highlighting the correlation between elevated

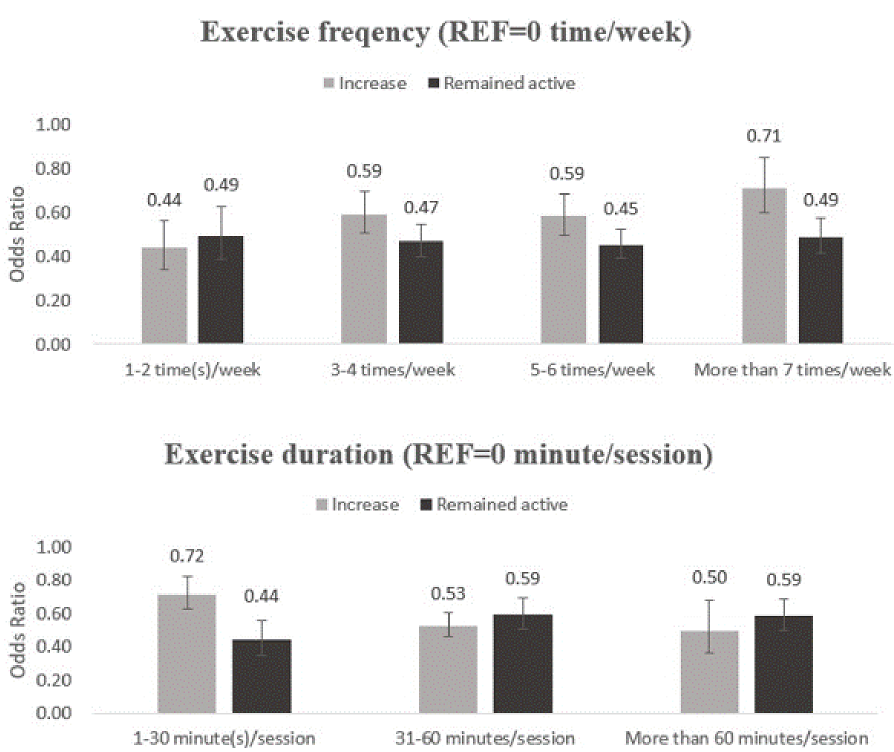

Figure 2 Results of subgroup analysis stratified by variables (2006–2022). *P value <0.001. REF, reference.

physical activity and decreased vulnerability to frailty. Third, regular physical activity promotes self-efficacy and results in the attenuation of depressive symptoms such as mental fatigue.[20] Physical activity is also known to enhance gait speed[20 21] and hinder the development of bradykinesia.[20] Fourth, exercise stimulates physiological changes in the body, resulting in improved brain function. Exercise stimulates the production of growth factors responsible for cerebral angiogenesis,[22 23] contributing to enhanced brain function and delayed neurodegeneration,[22] which can reduce frailty. Finally, engaging in greater levels of physical activity helps control blood pressure and cholesterol levels.[24] Exercise causes an immediate reduction in systolic blood pressure,[25] which normalises elevated blood pressure via the attenuation of sympathetic activity and arterial pressure.[24 26] This can lead to a reduced risk of type 2 diabetes mellitus and cardiovascular diseases,[24] subsequently lowering frailty risks because the FI encompasses several deficits related to chronic conditions such as hypertension, diabetes, stroke and heart disease.

Subgroup analyses and contextual factors

Subgroup analyses revealed that frailty was associated with several adverse consequences across physical, cognitive and social domains. Even among persistently active individuals (1–1), those residing in rural areas exhibited the highest ORs for frailty. Frailty tends to be more prevalent in rural areas due to limited access to healthcare services and resources than in urban and metropolitan areas.[27] Another plausible explanation is that individuals residing in rural areas often adopt less healthy lifestyles and have limited health awareness, making them more susceptible to frailty.[27] Given the multidimensional nature of frailty, it is important to recognise its several associated risk factors, including smoking.[28] Among the study participants, current smokers showed the highest ORs for frailty than did non-smokers and ex-smokers, especially when they increased their physical activity or remained persistently active. Smoking is considered a risk factor for frailty due to its potential involvement in the pathogenesis of frailty,[28] although the exact mechanism is not fully understood. However, it is well established that smoking is associated with the onset of cardiovascular diseases[28] such as hypertension, heart failure and stroke, all of which contribute to the health deficits included in FI calculations.

Limitations and strengths

This study had some limitations. First, cognitive function deficits measured using the K-MMSE were not included in the calculation of the FI due to restrictions on its usage. Consequently, the results of the GEE analysis in this study encompassed only the association between changes in physical activity and the FI, excluding cognitive function deficits. Despite this limitation, previous research has consistently demonstrated an association between increased cognitive function and a lower risk of frailty,[29–31] suggesting that excluding the cognitive function from FI calculation may not significantly impact the study results. Second, establishing a clear causal relationship between changes in physical activity and frailty was challenging. It remains uncertain whether alterations in physical activity precede frailty or vice versa. This limitation underscores the need to interpret the study findings cautiously. Third, establishing a clear causal relationship between the variables was not possible for this observational study. While the ORs of frailty in middle-aged adults with decreased physical activity were notably high, it remains uncertain whether these high ORs were solely attributable to specific medical conditions arising in middle age or if changes in exercise were the primary cause. It is worth noting that investigating whether the high OR of frailty was solely due to a medical condition could not be conducted in this study as most health-related variables were already accounted for as deficits when calculating FI. Fourth, the method used to collect data in KLoSA—computer-assisted personal interviews—raises concerns regarding the honesty of respondents. For instance, there is a possibility that respondents provided socially acceptable answers rather than truthful ones, leading to potential bias in the study results. Fifth, this study did not explore the relationship between frailty and specific types of physical activity. For example, resistance exercise training has been shown to enhance the strength and motor performance of older adults.[32] Nevertheless, combining aerobic and resistance exercises has been shown to be more effective in targeting specific aspects of frailty.[33] Thus, frailty is influenced not only by changes in physical activity but also by the type of exercise undertaken, a factor that was not explored in this study. Despite these limitations, this study analysed panel data across all age groups surveyed by the KLoSA rather than restricting the target population solely to older adults. This approach provided valuable insights into how age influences the relationship between changes in physical activity and frailty. The findings of this study can serve as crucial evidence for implementing interventions aimed at preventing the progression of frailty. Interventions to prevent frailty through physical activity should be initiated as early as the fourth decade of life. This recommendation is supported not only by previous literature[10] but also by the findings of this study.

Implications and recommendations

Notably, several implications can be derived from these findings. Given the association between longer workout durations and decreased frailty risk, individuals should prioritise lengthening their exercise sessions to prevent frailty. Furthermore, since this study found a stronger correlation between frailty and exercise duration compared with exercise frequency, this suggests that treatment should be adjusted based on individual progress[17] when prescribing physical activity to middle-aged and older adults. Merely increasing exercise frequency may not substantially aid in the prevention of frailty. This is indirectly linked to the findings of this study, which showed that increased physical activity may slightly lower frailty risk by improving factors related to ADL and IADL; its overall effect on reducing frailty may be limited. Conversely, changes in physical activity had minimal impact on the ORs of frailty in the analysis of chronic conditions, suggesting individual variations in frailty reduction are dependent on health status. This highlights the importance of further investigation into non-exercise-related risk factors, such as poor nutritional status,[34] which may be altered to lower frailty risks. Additionally, the South Korean government can use the findings of this study to implement health-related interventions aimed at preventing frailty among middle-aged and older adults. For instance, measures to increase awareness about frailty-related health issues could be particularly beneficial for individuals residing in rural areas. Moreover, recommendations aimed at enhancing intrinsic motivation or self-determination should be implemented to encourage proactive health behaviours.[35] Clinical assessments such as the Romberg test, used for assessing balance impairments, can also be conducted to identify individuals who may benefit from exercise interventions.[17]

CONCLUSION

This study revealed that persistent and increased physical activity was associated with a lower FI, which reduces the risk of frailty in middle-aged and older Korean adults. These results emphasise the crucial role of physical activity in promoting health, highlighting the necessity of regular physical activity in diminishing and preventing the risk of frailty in adults aged ≥45 years. However, further research is warranted to establish the most effective age range of initiation, frequency and duration of exercise for frailty prevention in this patient population. Additionally, it is imperative to investigate other potential frailty risk factors that include lifestyle behaviours, dietary patterns and acute or chronic medical conditions, which were not accounted for in this study. By doing so, the South Korean government can leverage comprehensive insights to implement targeted interventions aimed at enhancing the health of middle-aged and older adults, thereby mitigating the prevalence of frailty.

Author affiliations

[1]Medical Courses, Yonsei University College of Medicine, Seodaemun-gu, Republic of Korea

[2]Yonsei University Institute of Health Services Research, Seodaemun-gu, Seoul, Republic of Korea

[3]Department of Preventive Medicine, Yonsei University College of Medicine, Seodaemun-gu, Republic of Korea

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ORCID iDs

Yun Seo Jang http://orcid.org/0000-0001-5088-5407

Eun-Cheol Park http://orcid.org/0000-0002-2306-5398

REFERENCES

1 Korean Statistical Information Service. *Population projections and summary indicators*. Korea, 2023.
2 Takele MD, Sany K, Getie K, *et al*. Prevalence and associated factors of frailty among community dweller older adults living in Gondar town, northwest, Ethiopia: a community based cross-sectional study. *BMC Public Health* 2023;23:1309.
3 Walsh B, Fogg C, Harris S, *et al*. Frailty transitions and prevalence in an ageing population: longitudinal analysis of primary care data from an open cohort of adults aged 50 and over in England, 2006-2017. *Age Ageing* 2023;52:afad058.
4 Kang M, Kim OS, Hoogendijk EO, *et al*. Trends in Frailty Prevalence Among Older Adults in Korea: A Nationwide Study From 2008 to 2020. *J Korean Med Sci* 2023;38.
5 da Silva VD, Tribess S, Meneguci J, *et al*. Association between frailty and the combination of physical activity level and sedentary behavior in older adults. *BMC Public Health* 2019;19.
6 Sobhani A, Sharifi F, Fadayevatan R, *et al*. Low physical activity is the strongest factor associated with frailty phenotype and frailty index: data from baseline phase of Birjand Longitudinal Aging Study (BLAS). *BMC Geriatr* 2022;22:498.
7 McPhee JS, French DP, Jackson D, *et al*. Physical activity in older age: perspectives for healthy ageing and frailty. *Biogerontology* 2016;17:567–80.
8 Parra-Rizo MA, Sanchís-Soler G. Physical Activity and the Improvement of Autonomy, Functional Ability, Subjective Health, and Social Relationships in Women over the Age of 60. *Int J Environ Res Public Health* 2021;18:6926.
9 Seo YB, Oh YH, Yang YJ. Current Status of Physical Activity in South Korea. *Korean J Fam Med* 2022;43:209–19.

10 Gordon SJ, Baker N, Kidd M, *et al*. Pre-frailty factors in community-dwelling 40-75 year olds: opportunities for successful ageing. *BMC Geriatr* 2020;20:96.
11 Song H, Park J-H. Effects of Changes in Physical Activity with Cognitive Decline in Korean Home-Dwelling Older Adults. *J Multidiscip Healthc* 2022;15:333–41.
12 Searle SD, Mitnitski A, Gahbauer EA, *et al*. A standard procedure for creating a frailty index. *BMC Geriatr* 2008;8:24.
13 Kim S, Welsh DA, Cherry KE, *et al*. Association of healthy aging with parental longevity. *Age (Dordr)* 2013;35:1975–82.
14 Wang X, Hu J, Wu D. Risk factors for frailty in older adults. *Medicine (Baltimore)* 2022;101:e30169.
15 Lee HJ, Jang J, Choi D-W, *et al*. Association between change in lifestyle and cognitive functions among elderly Koreans: findings from the Korean longitudinal study of aging (2006-2016). *BMC Geriatr* 2020;20:317.
16 Lin Y-K, Chen C-Y, Cheung DST, *et al*. The relationship between physical activity trajectories and frailty: a 20-year prospective cohort among community-dwelling older people. *BMC Geriatr* 2022;22:867.
17 Angulo J, El Assar M, Álvarez-Bustos A, *et al*. Physical activity and exercise: Strategies to manage frailty. *Redox Biol* 2020;35:101513.
18 Corral-Pérez J, Casals C, Ávila-Cabeza-de-Vaca L, *et al*. Health factors associated with cognitive frailty in older adults living in the community. *Front Aging Neurosci* 2023;15:1232460.
19 Kehler DS, Theou O. The impact of physical activity and sedentary behaviors on frailty levels. *Mech Ageing Dev* 2019;180:29–41.
20 Huang T-Y, Chou M-Y, Liang C-K, *et al*. Physical activity plays a crucial role in multidomain intervention for frailty prevention. *Aging Clin Exp Res* 2023;35:1283–92.
21 Custodero C, Agosti P, Anton SD, *et al*. Effect of Physical Activity Intervention on Gait Speed by Frailty Condition: A Randomized Clinical Trial. *J Am Med Dir Assoc* 2023;24:489–96.
22 Morland C, Andersson KA, Haugen ØP, *et al*. Exercise induces cerebral VEGF and angiogenesis via the lactate receptor HCAR1. *Nat Commun* 2017;8:15557.
23 Harvard Health Publishing. *Exercise can boost your memory and thinking skills*. 2023.
24 Zhao W, Hu P, Sun W, *et al*. Effect of physical activity on the risk of frailty: A systematic review and meta-analysis. *PLoS One* 2022;17:e0278226.
25 Hegde SM, Solomon SD. Influence of Physical Activity on Hypertension and Cardiac Structure and Function. *Curr Hypertens Rep* 2015;17.
26 Tian D, Meng J. Exercise for Prevention and Relief of Cardiovascular Disease: Prognoses, Mechanisms, and Approaches. *Oxid Med Cell Longev* 2019;2019:3756750.
27 Xu R, Li Q, Guo F, *et al*. Prevalence and risk factors of frailty among people in rural areas: a systematic review and meta-analysis. *BMJ Open* 2021;11:e043494.
28 Kojima G, Iliffe S, Walters K. Smoking as a predictor of frailty: a systematic review. *BMC Geriatr* 2015;15:131.
29 Li F, Yan Y, Zheng L, *et al*. Frailty and its combined effects with lifestyle factors on cognitive function: a cross-sectional study. *BMC Geriatr* 2023;23:79.
30 Karanth S, Braithwaite D, Katsumata Y, *et al*. Association of Physical Frailty and Cognitive Function in a Population-Based Cross-Sectional Study of American Older Adults. *Gerontology* 2024;70:48–58.
31 Miyamura K, Fhon JRS, Bueno A de A, *et al*. Frailty syndrome and cognitive impairment in older adults: systematic review of the literature. *Rev Lat Am Enfermagem* 2019;27:e3202.
32 Liu CK, Fielding RA. Exercise as an intervention for frailty. *Clin Geriatr Med* 2011;27:101–10.
33 Aguirre LE, Villareal DT. Physical Exercise as Therapy for Frailty. *Nestle Nutr Inst Workshop Ser* 2015;83:83–92.
34 Cheong CY, Nyunt MSZ, Gao Q, *et al*. Risk Factors of Progression to Frailty: Findings from the Singapore Longitudinal Ageing Study. *J Nutr Health Aging* 2020;24:98–106.
35 Karim NA, Haron H, Abdullah N, *et al*. Intrinsic motivations for productive ageing. *IJEECS* 2019;13:1228.