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Association Between Chronic Diseases and Depressive Symptoms: A Generalized Estimating Equation Analysis of the Korean Longitudinal Study of Aging

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Abstract

Background

Depression is a major mental health problem among older adults and associated with physical health deterioration and social isolation. As population aging accelerates, the prevalence of chronic conditions and multimorbidity has increased, thereby increasing the risk of late-life depression. Social relationships are recognized as an important protective factor; however, longitudinal evidence on the long-term effects of chronic conditions and social relationships on depression, particularly across income levels, remains limited.

Methods

This study analyzed adults aged 65 years or older using data from five waves (2014–2022) of the Korean Longitudinal Study of Aging. Depression was measured using a validated short depression scale and dichotomized based on a standard cutoff. Chronic conditions were categorized as none, one, two, or more physician-diagnosed conditions. Social relationships were classified as high, middle, or low based on the frequency of contact with friends, relatives, or neighbors. Generalized estimating equation models were applied to examine concurrent and two-year lagged associations. Income-stratified analyses were conducted to assess socioeconomic differences.

Results

Numerous chronic conditions and lower levels of social relationships were associated with a significantly higher risk of depression. Multimorbidity increased the odds of subsequent depression by more than 30% in adjusted two-year lagged models, whereas low levels of social relationships were associated with approximately twice the risk of depression compared with high levels. Interaction effects between chronic conditions and social relationships were observed in selected analyses and did not show consistent patterns. Income-stratified analyses indicated that multimorbidity and low social relationships were associated with depression among low-income older adults, whereas social relationships showed a stronger association with depression than chronic conditions among high-income older adults.

Conclusions

Chronic conditions and social relationships were independently associated with depression in later life, with their relative importance varying by income level. These findings suggest the need for integrated and income-sensitive approaches that address physical health management and social relationship support to prevent depression among older adults.

Background

Population aging presents challenges that transcend the health problems of older individuals, affecting the organization, delivery, and sustainability of health care systems [1]. Health care systems are increasingly required to provide long-term and integrated care that addresses physical conditions and mental health needs because the prevalence of chronic diseases and multimorbidity increases among older adults [2]. Among mental health conditions, depression is one of the most common and burdensome problems in later life, associated with functional decline, increased health care utilization, and elevated mortality risk [3–5]. Globally, the prevalence of depression among older adults has remained consistently high over recent decades. Meta-analytic evidence estimates the prevalence of late-life depression at approximately 28%–32% [6], whereas a comprehensive review incorporating studies through 2023 reported prevalence rates of 19.2% and 16.5% for depression and anxiety, respectively, among older adults [7]. These findings indicate that depression in later life represents a persistent global public health issue rather than a problem confined to specific contexts. Depression in older adults is frequently accompanied by physical functional decline, social isolation, and the accumulation of chronic conditions, substantially reducing quality of life [8, 9]. Despite its high prevalence and burden, depression among older adults remains underdiagnosed and undertreated [10]. Depressive symptoms in later life are often misattributed to normal aging or regarded as secondary consequences of chronic physical illness, and older adults may be less likely to perceive mental health problems as conditions requiring clinical care [11]. In addition, limited consultation time, health care systems focused primarily on physical disease management, and fragmented delivery of mental and physical health services hinder the early detection and sustained management of depression [10]. In Korea, the burden of depression has become increasingly pronounced among older adults [12]. Concurrently, Korea is entering a super-aged society at one of the fastest rates among the Organization for Economic Co-operation and Development (OECD) countries [13], accompanied by a rapid increase in the prevalence of chronic diseases and multimorbidity [3]. Chronic conditions are well known to cause functional limitations, increase health care utilization, and reduce quality of life, and they have consistently been identified as major predictors of depressive symptoms [14]. Older adults with multimorbidity are at particularly high risk of depression owing to compounded physical decline and emotional vulnerability [5]. Social relationships also play a critical protective role in mental health during later life. Social interactions with family members, friends, and neighbors contribute to emotional stability and stress buffering, and greater social engagement has been associated with lower levels of depression and higher life satisfaction [15–17]. Conversely, the contraction of social networks due to retirement, bereavement, or physical limitations can intensify loneliness and social isolation, thereby increasing the risk of depression [6, 18].

Although previous studies have shown that chronic conditions and social relationships are significantly associated with depression in older populations, relatively insufficient research has examined whether social relationships moderate the association between chronic conditions and depression. Moreover, studies reflecting the sociocultural context of Korea, where family structures, social relationships, and welfare systems vary from those of Western countries, are insufficient. In addition, much of the existing

literature relies on cross-sectional data, thereby restricting the ability to account for temporal dynamics and causal ordering.

In this context, this study used longitudinal data from the Korean Longitudinal Study of Aging (KLoSA) to examine the associations between chronic conditions, social relationships, and depressive symptoms among adults aged 65 years or older. By applying contemporaneous and two-year lagged analyses, this study aimed to capture the short- and long-term effects of chronic conditions and social relationships on depression in later life. By highlighting older adults' mental health from the perspective of interactions between physical health and social resources, this study sought to provide empirical evidence to inform integrated strategies for depression prevention and intervention that combine chronic disease management with the strengthening of social relationships.

Methods

Data source and study population

This study used data from the KLoSA, a nationally representative longitudinal survey of adults aged 45 years or older in Korea, excluding Jeju Island, conducted by the Korea Employment Information Service. The survey used a stratified multistage cluster sampling design based on region and housing type, using enumeration districts from the 2005 Population and Housing Census as the sampling frame [19]. Notably, KLoSA collects detailed information on sociodemographic characteristics, health status, employment and retirement, income and assets, and quality of life. Refresher samples were excluded to reduce cohort heterogeneity due to panel attrition, and respondents from the original cohort who participated in the first wave in 2006 were included [20]. The analytic sample comprised five survey waves (Wave 5–9; 2014–2022). At each wave, individuals aged 65 years or older were included. After excluding observations with missing values on key variables, a total of 21,294 repeated observations were included in the final analysis. Sample sizes by wave included 4,136 (2014), 4,250 (2016), 4,207 (2018), 4,323 (2020), and 4,378 (2022) (Fig. 1).

Variables

Dependent variable: Depressive symptoms

Depressive symptoms were measured using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D10). Items were rated on a 4-point Likert scale, with two positively worded items reverse coded. Total scores ranged from 0 to 30, with higher scores indicating more severe depressive symptoms. Consistent with established cutoffs, scores ≥ 10 were classified as indicative of depressive symptoms [21, 22]. The internal consistency of the CES-D10 was high (Cronbach's α = 0.855) [23].

Independent variable: Chronic conditions

Chronic conditions were assessed by summing self-reported physician diagnoses of hypertension, diabetes mellitus, chronic lung disease, heart disease, cerebrovascular disease, arthritis, and rheumatism (range: 0–6). Based on previous studies, the number of chronic conditions was categorized as none, one, two, or more [24, 25].

Moderating variable: Social relationships

Social relationships were measured by the frequency of contact with friends, relatives, and neighbors. Responses were recategorized into three levels: high (at least once per week), middle (one to two times per month), and low (six times per year or less or no contact) [17].

Covariates

Covariates included sex, age group (65–74 years, ≥ 75 years), educational attainment, marital status, residential area, equivalized household income (low, middle, and high), type of health insurance, economic activity status, and religious affiliation. Health-related factors included smoking status, alcohol consumption, regular physical activity, self-rated health, and instrumental activities of daily living (IADL). Notably, IADL was considered a continuous variable ranging from 0 to 10, with higher scores indicating greater functional limitations (Table 1).

Table 1
Definition of study variables

Classification	Variable	Categories
Dependent variable	Depressive symptoms	Yes, No
Independent variable	Chronic conditions	0, 1, 2 or more
Moderating variable	Social relationships	High, Middle, Low
Covariates	Sex	Male, Female
	Age group	65–74 years, ≥ 75 years
	Education	Less than middle school, Middle school or higher
	Marital status	Married, Unmarried (separated/divorced/widowed/never married)
	Residential area	Large city, Small or medium-sized city, Rural area
	Equivalized household income	Low, Middle, High
	Type of health insurance	Employee-based insurance, Self-employed insurance, Medical Aid
	Economic activity	Yes, No
	Religion	Yes, No
	Smoking status	Never smoked, Former smoker, Current smoker
	Alcohol status	Non-drinker, Former drinker, Current drinker
	Regular physical activity	Yes, No
	Self-rated health	Good, Fair, Poor
	Instrumental activities of daily living	0–10 (higher scores indicate greater functional limitations)

Statistical analysis

Descriptive statistics were used to summarize participants' characteristics. Categorical variables were presented as frequencies and percentages and continuous variables as means and standard errors. Differences across survey years were assessed using chi-square and Kruskal–Wallis tests for categorical and continuous variables, respectively. All analyses applied sampling weights to account for the complex survey design.

Generalized estimating equations (GEE) were used to account for within-individual correlations in repeated observations. Depressive symptoms were modeled as a binary outcome using a binomial distribution with a logit link to estimate odds ratios (ORs) and 95% confidence intervals (CIs). An exchangeable working correlation structure was specified.

Analyses followed a stepwise modeling approach: chronic conditions were entered first, followed by social relationships, then an interaction term between chronic conditions and social relationships to test moderation (Table 2). Subsequently, fully adjusted models incorporated sociodemographic and health-related covariates. To account for temporal ordering, two-year lagged GEE models were estimated to examine the effects of chronic conditions and social relationships at time *t* on depressive symptoms at time *t* + 2. Income-stratified subgroup analyses were also conducted to assess potential differences by household income. Model fit was evaluated using the quasi-likelihood under the independence model criterion (QIC) and QICu, with lower values indicating better fit [26]. Statistical significance was set at $p < 0.05$, and all analyses were performed using SAS version 9.4.

Table 2
Specification of analytical models

Models		Variables
Unadjusted models	1	Chronic conditions
	2	Chronic conditions, Social relationships
	3	Chronic conditions, Social relationships, Interaction term (chronic condition × social relationships)
Adjusted models	4	Model 1 + control variables
	5	Model 2 + control variables
	6	Model 3 + control variables

Ethical considerations

This study was granted an exemption from ethical review by the Institutional Review Board of Kongju National University (Approval number: KNU_IRB_2025-059).

Results

Characteristics of the study population and year-specific distributions

The analytic sample included 4,136 adults aged ≥ 65 years in 2014, 4,250 in 2016, 4,207 in 2018, 4,323 in 2020, and 4,378 in 2022. Year-specific descriptive statistics are presented in Additional File 1. The

prevalence of depressive symptoms declined from 27.6% in 2014 to 22.3% in 2022 ($p < 0.001$). The distribution of the number of chronic conditions (0, 1, and ≥ 2) did not vary significantly across survey years ($p = 0.456$). By contrast, social relationships varied significantly over time ($p < 0.001$). The proportion with high levels of social relationships decreased from 60.6% in 2014 to 50.2% in 2020 and increased to 57.0% in 2022 (Fig. 2). Significant year-to-year differences were also observed for age, educational attainment, residential area, equivalized household income, type of health insurance, religious affiliation, smoking status, alcohol consumption, regular physical activity, self-rated health, and IADL ($p < 0.05$).

Cross-sectional GEE analysis

In unadjusted cross-sectional GEE models, the risk of depressive symptoms was 1.31 and 1.97 times higher among individuals with one chronic condition and those with two or more, respectively. In models including social relationships, having two or more chronic conditions was associated with a 1.83-fold higher risk of depression, whereas low levels of social relationships were associated with a 2.67-fold higher risk compared with high levels. Interaction terms between chronic conditions and social relationships were not statistically significant (Additional File 2).

In adjusted models (Table 3), having two or more chronic conditions was associated with an increased risk of depression (approximately 1.13–1.20-fold; $p < 0.05$), whereas low levels of social relationships were associated with substantially higher risk (OR = 2.26–2.72; $p < 0.001$). Some interaction terms were statistically significant, but patterns were not consistent. Residence in small or medium-sized cities, low income, and economic inactivity were associated with higher risk for unmarried status ($p < 0.001$). Regular physical activity showed a protective effect (OR = 0.82–0.85; $p < 0.001$). Poor self-rated health was associated with up to a threefold increase in risk (OR = 2.95–3.03; $p < 0.001$), whereas higher IADL scores were associated with increased risk. The sensitivity analyses using a continuous measure of depressive symptoms showed similar patterns across the cross-sectional GEE models (Additional Files 4 and 5).

[Table 3 here]

Two-year lagged GEE analysis

Chronic conditions were significantly associated with depressive symptoms two years later in unadjusted two-year lagged GEE analyses. Having one and two or more chronic conditions increased risk by approximately 1.21–1.26 and 1.83–1.90 times, respectively. Compared with high levels of social relationships, middle and low levels were associated with approximately 1.14–1.26 and 2.14–2.16 times higher risks, respectively. Interaction terms were not statistically significant (Additional File 3).

In adjusted two-year lagged models (Table 4), having two or more chronic conditions was associated with a 1.30–1.34-fold higher risk of depression ($p < 0.001$). Middle and low levels of social relationships were associated with approximately 1.18–1.30 and 1.94–2.03 times higher risks, respectively ($p < 0.05$). The relationship between chronic conditions and social relationships was nonsignificant. Age ≥ 75 years,

lower education, residence in small or medium-sized cities, low income, and Medical Aid status were associated with higher risk. Economic activity and regular physical activity were protective (OR = 0.70–0.71; $p < 0.001$). Poor self-rated health increased risk by approximately 1.5-fold (OR = 1.50–1.51; $p < 0.001$), and higher IADL scores were associated with increased risk (OR = 1.06–1.07; $p < 0.001$). The sensitivity analyses using continuous depressive symptom scores in the two-year lagged GEE models yielded broadly similar associations for the main variables (Additional Files 6 and 7).

[Table 4 here]

Income-stratified two-year lagged GEE subgroup analysis

Based on model fit indices (QIC and QICu), Models 5 and 6 showed the best fit and were selected as the final models (Table 5). Considering potential cumulative or delayed effects of chronic conditions, income-stratified analyses focused on the two-year lagged GEE models.

Table 5
Model fit statistics for cross-sectional and two-year lagged GEE models

Model fit		Cross-sectional		Two-year-lagged	
		QIC	QICu	QIC	QICu
Crude	Model 1	23492.34	23487.96	16843.69	16840.24
	Model 2	22355.91	22351.91	16275.95	1272.61
	Model 3	22358.45	22354.18	16281.58	16277.71
Adjusted (Adj.)	Model 4	21370.51	21353.98	15930.95	15916.27
	Model 5	20780.01	20764.22	15596.10	15582.39
	Model 6	20779.11	20762.82	15602.15	15587.77

Note. Lower values of the quasi-likelihood under the independence model criterion (QIC) and QICu indicated better model fit.

Low-income group

Multimorbidity (≥ 2 conditions) was associated with higher risk of depressive symptoms two years later (OR ≈ 1.25–1.29), whereas a single condition was not. Low social relationships were associated with higher risk (OR ≈ 1.66–1.80; $p < 0.001$). Interaction terms were not significant. Residence in small or medium-sized cities, unmarried status, and greater IADL limitations increased risk, whereas economic activity and regular physical activity were protective (Table 6).

[Table 6 here]

Middle-income group

Having two or more chronic conditions increased risk (OR ≈ 1.29–1.38; $p < 0.01$). Low social relationships were strongly associated with depression (OR ≈ 2.03–2.25; $p < 0.001$). Some models suggested attenuation of the effect of a single condition at middle levels of social relationships; however, interaction effects were not consistent. Older age, lower education, residence in small or medium-sized cities, and greater IADL limitations increased risk, and economic activity was protective (Table 7).

[Table 7 here]

High-income group

No significant association was observed between chronic conditions and depression. By contrast, low social relationships showed a strong association with depression (OR ≈ 3.60–3.85; $p < 0.001$). All interaction terms were nonsignificant. Residence in small or medium-sized cities and greater IADL limitations increased risk, whereas economic activity, religious affiliation, and regular physical activity were protective (Table 8).

[Table 8 here]

Discussion

This study examined the effects of chronic conditions and social relationships on depressive symptoms among older adults in Korea using cross-sectional and two-year lagged GEE analyses and explored the potential moderating role of social relationships across income groups. The findings indicated that chronic conditions and social relationships were major risk factors for depression, and these associations were largely consistent in the analyses accounting for temporal lag. The moderating effect of social relationships was observed only in some analyses, suggesting that caution should be exercised in generalizing these findings. Although this study used longitudinal data from Korea, population aging, the increasing prevalence of chronic conditions, and declining social relationships are common across many countries; therefore, the findings may be interpreted within a broader international context.

Association between chronic conditions and depression

The finding that the risk of depression increases with a greater number of chronic conditions is consistent with previous domestic and international studies. Major chronic conditions, such as hypertension, diabetes, cardiovascular disease, and arthritis, have been shown to contribute to late-life depression through functional decline, pain, and increased health care utilization [9, 14]. In particular, multimorbidity has been reported to increase the risk of depression more than single conditions because functional limitations and reductions in quality of life tend to accumulate over time [3, 5, 27].

The persistence of the effects of multimorbidity in the two-year lagged analyses suggests that the mental health impact of chronic conditions is not limited to short-term effects but may accumulate or emerge with delay over time. This finding is consistent with previous Korean longitudinal studies

showing that depressive trajectories in later life are related to declining physical health and increasing functional vulnerability among older adults [28, 29]. Moreover, international longitudinal studies focusing on limitations in activities of life—a vital indicator of physical health deterioration—have demonstrated a bidirectional relationship between chronic conditions and depression. Wang et al. reported that limitations in activities of life significantly increased depressive symptoms, whereas depression exacerbated functional decline [30]. Similarly, Zhu et al. identified a mutually reinforcing cycle between limitations in activities of life and IADL as well as depressive symptoms [31]. These findings suggest that multimorbidity constitutes a critical risk factor for late-life depression, which reflects a broadly shared phenomenon rather than one confined to a specific national context.

Social relationships and depression

Social relationships were identified as a crucial factor associated with depression among older adults. The finding that more frequent contact with family members, friends, and neighbors is associated with a lower risk of depression is consistent with previous Korean studies [15, 17, 32] as well as international longitudinal studies and meta-analyses [6, 18, 33]. Notably, the persistence of increased depression risk among individuals with poor social relationships at the concurrent time point and two years later suggests that social isolation and loneliness may not serve as transient states but as enduring risk factors for mental health problems [34, 35]. This supports the perspective that the importance of social relationships for mental health in later life transcends specific cultural contexts and represents a common concern across aging societies.

Theoretical perspectives have suggested that social relationships in later life serve as essential resources that transcend emotional support to influence stress regulation and the maintenance of health-related behaviors. Berkman and Glass proposed structural approaches through which social integration and networks affect individual health [36], emphasizing that social relationships buffer exposure to stress and provide a foundation for promoting health-related behaviors. Cohen and Wills explained how social support can reduce the occurrence of mental health problems by modulating psychological and physiological responses under stressful conditions through the stress-buffering hypothesis [37]. In addition, Thoits highlighted how social relationships influence physical and mental health by facilitating self-regulation, role identity maintenance, and continuity of health behavior [38]. Collectively, these perspectives underscore that social relationships in later life can have indirect yet sustained effects on mental health outcomes such as depression. Furthermore, considering later life transitions such as retirement, spousal loss, and declining physical functioning, which often lead to declining social networks [39, 40], weakened social relationships should be understood as a structural factor that intensifies the risk of depression among older adults.

Interpretation of the moderating effect of social relationships

The evidence that social relationships moderated the association between chronic conditions and depression is inconsistent. Although interaction terms were statistically significant in some cross-

sectional and subgroup analyses of the middle-income group, similar patterns were not consistently observed across the two-year lagged or income-stratified analyses. These findings are partially consistent with previous studies suggesting that social support buffers the negative mental health effects of multimorbidity [41, 42]. Rather than indicating a universally operating moderating effect, these results suggest that the buffering role of social relationships may vary depending on context and conditions.

These discrepancies may be attributed to temporal context, differences in the measurement, and qualitative characteristics of social relationships. The indicator of social relationships used in this study focused on the frequency of contact and may not have fully captured functional aspects such as emotional or instrumental support [43]. In addition, the buffering effects of social relationships may be more pronounced in specific stressful situations or during short-term crisis [44, 45] and, thus, may have appeared attenuated in the longer-term lagged analyses.

Implications of income-related differences

The income-stratified subgroup analyses demonstrated that the effects of chronic conditions and social relationships operate differently depending on the socioeconomic context. Multimorbidity and low levels of social relationships were associated with an increased risk of depression, indicating an overlapping structure of health and social vulnerability in the low-income group. This finding is consistent with previous studies suggesting that the burden of chronic conditions is more likely to translate into mental health problems among socioeconomically disadvantaged populations [3, 46]. Chronic conditions and social relationships were associated with depression, and some analyses suggested that social relationships may partially attenuate the effects of having a single chronic condition in the middle-income group. By contrast, the impact of chronic conditions was not pronounced among the high-income group, whereas the level of social relationships showed the strongest association with depression risk. This pattern suggests that social isolation and the quality of social relationships may be critical in mental health than physical illness among individuals with sufficient economic resources [34, 35]. Overall, these findings highlight the importance of considering the socioeconomic context in understanding mental health outcomes among older adults.

Significance and limitations of the study

The significance of this study lies in using nationally representative longitudinal data on older adults in Korea to examine the effects of chronic conditions and social relationships on depression using contemporaneous and lagged analyses. In particular, this study accounted for heterogeneity in the older population and highlighted the need for customized approaches based on the socioeconomic context rather than uniform interventions by conducting income-stratified subgroup analyses. Nevertheless, this study has several limitations. As an observational study, it could not establish causal relationships and did not fully capture the severity or specific combinations of chronic conditions, nor the qualitative and functional aspects of social relationships. Future research should incorporate more detailed measures of disease characteristics and social support as well as analyses using various time intervals. Korea is

entering a super-aged society at a much faster pace than most OECD countries [47], and this rapid population aging further underscores the increasing importance of mental health issues among older adults. In this context, the findings of this study may provide meaningful empirical evidence for other countries seeking to prepare for future population aging.

Conclusions

Using longitudinal data on adults aged 65 years or older in Korea, this study examined the associations between chronic conditions, social relationships, and depressive symptoms. The findings showed that numerous chronic conditions and lower levels of social relationships were significantly associated with an increased risk of depression. The moderating effect of social relationships was observed in some analyses, suggesting that chronic conditions and social relationships generally operate as independent factors in relation to depression. Income-stratified analyses indicated that multimorbidity and poor social relationships were associated with depression in the low-income group, whereas the level of social relationships was relatively strongly associated with depressive symptoms in the high-income group. Overall, these findings suggest that late-life depression can be attributed to a combination of health status, social relationships, and socioeconomic context and highlight the need for stratified approaches to mental health policy for older adults that integrate physical health management while strengthening social relationships.

Abbreviations

Organization for Economic Co-operation and Development (OECD)

Korean Longitudinal Study of Aging (KLoSA)

10-item Center for Epidemiologic Studies Depression Scale (CES-D10)

Instrumental activities of daily living (IADL)

Generalized estimating equations (GEE)

Independence model criterion (QIC)

Declarations

Ethics approval and consent to participate

This study was granted an exemption from ethical review by the Institutional Review Board of Kongju National University (Approval number: KNU_IRB_2025-059). The study used de-identified secondary data; therefore, informed consent was not required.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analyzed during the current study are available from the Korea Labor Institute. The authors do not have permission to share the data.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

W.J.S. conducted the analysis and drafted the manuscript. M.J.R. and G.U.H. contributed to manuscript revisions. S.H.L. supervised the study. All authors read and approved the final manuscript.

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Tables

Table 3. Adjusted odds ratios for depressive symptoms from cross-sectional GEE models

Variable	Adjusted (Adj.)		
	Model 4	Model 5	Model 6
	Adj. OR (95% CI)	Adj. OR (95% CI)	Adj. OR (95% CI)
Chronic conditions (ref: 0)			
1	1.02 (0.907–1.139)	0.99 (0.880–1.106)	1.03 (0.894–1.193)
2 or more	1.16 (1.031–1.300)*	1.13 (1.007–1.267)*	1.20 (1.038–1.377)*
Social relationships (ref: High)			
Middle		1.16 (1.063–1.277)**	1.12 (0.918–1.364)
Low		2.26 (2.070–2.474)***	2.72 (2.232–3.320)***
Chronic condition × Social relationships (ref: 0 × High)			
1 × Middle			1.04 (0.808–1.342)
1 × Low			0.82 (0.644–1.045)
2 or more × Middle			1.06 (0.839–1.350)
2 or more × Low			0.78 (0.622–0.987)*
Sex (ref: Male)			
Female	1.00 (0.865–1.165)	1.02 (0.882–1.167)	1.02 (0.880–1.180)
Age group (ref: 65–74 years)			
≥75 years	0.99 (0.908–1.076)	0.98 (0.897–1.067)	0.98 (0.897–1.067)
Education (ref: Less than middle school)			
Middle school or higher	1.03 (0.928–1.147)	1.02 (0.918–1.132)	1.02 (0.918–1.133)
Marital status (ref: Married)			
Unmarried	1.39 (1.260–1.537)***	1.45 (1.309–1.596)***	1.44 (1.305–1.591)***
Residential area (ref: Large city)			
Small or medium-sized city	1.57 (1.414–1.735)***	1.51 (1.363–1.668)***	1.51 (1.364–1.670)***

Rural area	0.96 (0.859–1.069)	1.04 (0.930–1.161)	1.04 (0.929–1.162)
Equivalized household income (ref: High)			
Middle	1.08 (0.976–1.192)	1.09 (0.982–1.200)	1.08 (0.981–1.198)
Low	1.25 (1.118–1.395)***	1.28 (1.145–1.429)***	1.28 (1.142–1.426)***
Type of health insurance (ref: Employee-based insurance)			
Self-employed insurance	1.02 (0.938–1.119)	1.04 (0.950–1.135)	1.04 (0.950–1.134)
Medical Aid	1.18 (1.024–1.369)*	1.15 (0.992–1.331)	1.15 (0.992–1.331)
Economic activity (ref: No)			
Yes	0.70 (0.628–0.777)***	0.71 (0.638–0.789)***	0.71 (0.637–0.791)***
Religion (ref: No)			
Yes	0.91 (0.847–0.981)*	0.97 (0.903–1.047)	0.97 (0.902–1.047)
Smoking status (ref: Never smoked)			
Former smoker	0.98 (0.855–1.134)	0.97 (0.845–1.121)	0.97 (0.843–1.119)
Current smoker	0.92 (0.761–1.115)	0.90 (0.746–1.098)	0.90 (0.745–1.097)
Alcohol status (ref: Non-drinker)			
Former drinker	1.15 (1.016–1.304)*	1.10 (0.968–1.244)	1.10 (0.968–1.245)
Current drinker	1.04 (0.872–1.183)	1.02 (0.892–1.161)	1.02 (0.892–1.161)
Regular physical activity (ref: No)			
Yes	0.82 (0.757–0.882)***	0.85 (0.786–0.919)***	0.85 (0.785–0.919)***
Self-rated health (ref: Good)			
Fair	1.67 (1.489–1.880)***	1.66 (1.474–1.867)***	1.66 (1.474–1.866)***

Poor	3.03 (2.668–3.430)***	2.95 (2.593–3.350)***	2.95 (2.594–3.350)***
Instrumental activities of daily living	1.11 (1.094–1.125)***	1.09 (1.070–1.102)***	1.09 (1.071–1.103)***
Year (ref: 20222)			
2014	1.18 (1.065–1.300)**	1.21 (1.090–1.337)***	1.20 (1.085–1.331)***
2016	1.08 (0.978–1.184)	1.13 (1.025–1.250)*	1.13 (1.023–1.246)*
2018	1.13 (1.031–1.247)**	1.14 (1.034–1.257)***	1.14 (1.032–1.251)*
2020	0.94 (0.855–1.032)	0.89 (0.807–0.981)*	0.89 (0.807–0.979)*

Table 4. Adjusted odds ratios for depressive symptoms from two-year lagged GEE models

Variable	Two-year-lagged Adjusted (Adj.)		
	Model 4	**Model 5**	**Model 6**
	Adj. OR (95% CI)	**Adj. OR (95% CI)**	**Adj. OR (95% CI)**
Chronic conditions (ref: 0)			
1	1.03 (0.911–1.168)	1.02 (0.897–1.150)	1.07 (0.920–1.255)
2 or more	1.32 (1.161–1.489)***	1.30 (1.145–1.465)***	1.34 (1.150–1.554)***
Social relationships (ref: High)			
Middle		1.18 (1.068–1.315)**	1.30 (1.060–1.600)*
Low		1.94 (1.752–2.153)***	2.03 (1.612–2.566)***
Chronic condition × Social relationships (ref: 0 × High)			
1 × Middle			0.85 (0.649–1.114)
1 × Low			0.92 (0.688–1.225)
2 or more × Middle			0.91 (0.700–1.176)
2 or more × Low			0.96 (0.732–1.261)
Sex (ref: Male)			
Female	0.98 (0.834–1.157)	1.00 (0.847–1.167)	1.00 (0.848–1.167)
Age group (ref: 65–74 years)			
≥75 years	1.17 (1.065–1.287)**	1.15 (1.048–1.271)**	1.15 (1.049–1.271)**
Education (ref: Less than middle school)			
Middle school or higher	1.18 (1.053–1.327)**	1.17 (1.048–1.316)**	1.17 (1.048–1.316)**
Marital status (ref: Married)			
Unmarried	1.08 (0.969–1.210)	1.12 (1.004–1.252)*	1.12 (1.003–1.252)*
Residential area (ref: Large city)			
Small or medium-sized city	1.71 (1.526–1.911)***	1.64 (1.464–1.825)***	1.64 (1.464–1.825)***

Rural area	0.91 (0.806–1.026)	0.97 (0.857–1.092)	0.97 (0.856–1.091)
Equivalized household income (ref: High)			
Middle	1.08 (0.959–1.212)	1.08 (0.962–1.216)	1.08 (0.962–1.216)
Low	1.31 (1.150–1.480)***	1.34 (1.180–1.519)***	1.34 (1.180–1.519)***
Type of health insurance (ref: Employee-based insurance)			
Self-employed insurance	1.10 (0.992–1.213)	1.09 (0.984–1.199)	1.09 (0.984–1.199)
Medical Aid	1.25 (1.047–1.485)*	1.21 (1.017–1.443)*	1.21 (1.017–1.443)*
Economic activity (ref: No)			
Yes	0.70 (0.622–0.783)***	0.71 (0.631–0.799)***	0.71 (0.631–0.799)***
Religion (ref: No)			
Yes	0.93 (0.858–1.011)	0.98 (0.903–1.066)	0.98 (0.903–1.066)
Smoking status (ref: Never smoked)			
Former smoker	1.00 (0.857–1.173)	1.00 (0.855–1.167)	1.00 (0.855–1.167)
Current smoker	0.93 (0.758–1.145)	0.94 (0.761–1.148)	0.94 (0.761–1.148)
Alcohol status (ref: Non-drinker)			
Former drinker	1.03 (0.895–1.184)	0.98 (0.852–1.130)	0.98 (0.852–1.130)
Current drinker	1.07 (0.933–1.237)	1.06 (0.919–1.216)	1.06 (0.919–1.216)
Regular physical activity (ref: No)			
Yes	0.83 (0.761–0.905)***	0.85 (0.780–0.930)***	0.85 (0.780–0.930)***
Self-rated health (ref: Good)			
Fair	1.22 (1.087–1.374)***	1.22 (1.084–1.375)***	1.22 (1.084–1.375)***
Poor	1.51 (1.330–1.722)***	1.50 (1.313–1.707)***	1.50 (1.313–1.707)***
Instrumental activities of daily living	1.07 (1.054–1.094)***	1.06 (1.037–1.079)***	1.06 (1.037–1.079)***

Table 6. Income-stratified two-year lagged GEE analysis: Low-income group

Variable	Low-income group	
	Model 5	Model 6
	Adj. OR (95% CI)	Adj. OR (95% CI)
Chronic conditions (ref: 0)		
1	0.99 (0.818–1.202)	0.98 (0.771–1.240)
2 or more	1.29 (1.068–1.550)**	1.25 (0.998–1.566)†
Social relationships (ref: High)		
Middle	1.16 (0.977–1.376)	1.15 (0.793–1.682)
Low	1.80 (1.550–2.094)***	1.66 (1.613–2.366)**
Chronic condition × Social relationships (ref: 0 × High)		
1 × Middle		1.13 (0.705–1.799)
1 × Low		1.00 (0.644–1.553)
2 or more × Middle		0.93 (0.593–1.454)
2 or more × Low		1.17 (0.778–1.753)
Sex (ref: Male)		
Female	1.01 (0.800–1.272)	1.01 (0.798–1.269)
Age group (ref: 65–74 years)		
≥75 years	1.12 (0.971–1.289)	1.12 (0.969–1.288)
Education (ref: Less than middle school)		
Middle school or higher	1.06 (0.899–1.254)	1.07 (0.902–1.258)
Marital status (ref: Married)		
Unmarried	1.22 (1.047–1.429)*	1.23 (1.049–1.431)*
Residential area (ref: Large city)		
Small or medium-sized city	1.49 (1.264–1.749)***	1.48 (1.256–1.741)***
Rural area	0.95 (0.799–1.122)	0.94 (0.797–1.119)
Type of health insurance (ref: Employee-based insurance)		
Self-employed insurance	1.20 (1.023–1.419)*	1.21 (1.025–1.422)*
Medical Aid	1.11 (0.903–1.365)	1.11 (0.900–1.360)

Economic activity (ref: No)		
Yes	0.66 (0.539–0.799)***	0.66 (0.540–0.800)***
Religion (ref: No)		
Yes	1.09 (0.963–1.231)	1.09 (0.965–1.234)
Smoking status (ref: Never smoked)		
Former smoker	1.09 (0.867–1.365)	1.09 (0.868–1.366)
Current smoker	1.02 (0.743–1.392)	1.02 (0.748–1.400)
Alcohol status (ref: Non-drinker)		
Former drinker	0.90 (0.725–1.106)	0.90 (0.726–1.107)
Current drinker	1.00 (0.809–1.224)	1.00 (0.811–1.228)
Regular physical activity (ref: No)		
Yes	0.86 (0.750–0.988)*	0.86 (0.749–0.986)*
Self-rated health (ref: Good)		
Fair	0.95 (0.778–1.158)	0.95 (0.780–1.161)
Poor	1.30 (1.055–1.591)*	1.30 (1.057–1.594)*
Instrumental activities of daily living	1.06 (1.035–1.093)***	1.06 (1.035–1.093)***
†$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$		

Table 7. Income-stratified two-year lagged GEE analysis: Middle-income group

Variable	Middle-income group	
	Model 5	Model 6
	Adj. OR (95% CI)	Adj. OR (95% CI)
Chronic conditions (ref: 0)		
1	0.98 (0.811–1.178)	1.16 (0.915–1.566)
2 or more	1.29 (1.075–1.547)**	1.38 (1.092–1.742)**
Social relationships (ref: High)		
Middle	1.17 (0.997–1.372)†	1.48 (1.103–1.976)**
Low	2.03 (1.728–2.378)***	2.25 (1.617–3.131)***
Chronic condition × Social relationships (ref: 0 × High)		
1 × Middle		0.59 (0.389–0.894)*
1 × Low		0.81 (0.533–1.243)
2 or more × Middle		0.85 (0.575–1.244)
2 or more × Low		0.91 (0.613–1.753)
Sex (ref: Male)		
Female	1.10 (0.859–1.397)	1.09 (0.857–1.396)
Age group (ref: 65–74 years)		
≥75 years	1.18 (1.016–1.373)*	1.18 (1.018–1.376)*
Education (ref: Less than middle school)		
Middle school or higher	1.20 (1.019–1.412)*	1.20 (1.018–1.416)*
Marital status (ref: Married)		
Unmarried	1.04 (0.879–1.237)	1.04 (1.876–1.233)
Residential area (ref: Large city)		
Small or medium-sized city	1.56 (1.330–1.841)***	1.57 (1.332–1.847)***
Rural area	0.97 (0.804–1.178)	0.97 (0.802–1.175)
Type of health insurance (ref: Employee-based insurance)		
Self-employed insurance	1.07 (0.922–1.248)	1.08 (0.926–1.254)
Medical Aid	1.39 (0.997–1.927)†	1.39 (0.998–1.948)†

Economic activity (ref: No)		
Yes	0.79 (0.666–0.928)**	0.79 (0.666–0.929)**
Religion (ref: No)		
Yes	0.97 (0.853–1.108)	0.97 (0.854–1.110)
Smoking status (ref: Never smoked)		
Former smoker	1.15 (0.911–1.457)	1.15 (0.908–1.454)
Current smoker	1.06 (0.792–1.430)	1.07 (0.794–1.438)
Alcohol status (ref: Non-drinker)		
Former drinker	1.04 (0.843–1.281)	1.03 (0.839–1.276)
Current drinker	1.12 (0.917–1.378)	1.12 (0.912–1.374)
Regular physical activity (ref: No)		
Yes	0.93 (0.807–1.063)	0.93 (0.809–1.065)
Self-rated health (ref: Good)		
Fair	1.55 (1.279–1.869)***	1.55 (1.285–1.879)***
Poor	1.91 (1.547–2.354)***	1.91 (1.508–2.360)***
Instrumental activities of daily living	1.06 (1.033–1.098)***	1.06 (1.032–1.097)***
†$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$		

Table 8. Income-stratified two-year lagged GEE analysis: High-income group

Variable	High-income group	
	Model 5	Model 6
	Adj. OR (95% CI)	Adj. OR (95% CI)
Chronic conditions (ref: 0)		
1	1.02 (0.770–1.350)	1.06 (0.718–1.571)
2 or more	1.17 (0.865–1.572)	1.20 (0.800–1.809)
Social relationships (ref: High)		
Middle	1.31 (1.004–1.716)*	1.35 (0.808–2.252)
Low	3.60 (2.796–4.641)***	3.85 (2.261–6.551)***
Chronic condition × Social relationships (ref: 0 × High)		
1 × Middle		0.93 (0.483–1.803)
1 × Low		0.92 (0.473–1.808)
2 or more × Middle		1.00 (0.497–1.978)
2 or more × Low		0.91 (0.473–1.754)
Sex (ref: Male)		
Female	0.76 (0.546–1.061)	0.76 (0.546–1.063)
Age group (ref: 65–74 years)		
≥75 years	1.22 (0.939–1.575)	1.22 (0.939–1.576)
Education (ref: Less than middle school)		
Middle school or higher	1.24 (0.938–1.726)	1.24 (0.936–1.637)
Marital status (ref: Married)		
Unmarried	1.08 (0.808–1.455)	1.08 (0.804–1.455)
Residential area (ref: Large city)		
Small or medium-sized city	2.16 (1.686–2.763)***	2.15 (1.685–2.752)***
Rural area	0.93 (0.666–1.310)	0.93 (0.665–1.311)
Type of health insurance (ref: Employee-based insurance)		
Self-employed insurance	1.03 (0.822–1.282)	1.03 (0.812–1.281)
Medical Aid	1.38 (0.692–2.739)	1.37 (0.688–2.739)

Economic activity (ref: No)		
Yes	0.57 (0.434–0.749)***	0.57 (0.433–0.748)***
Religion (ref: No)		
Yes	0.81 (0.651–0.994)*	0.81 (0.651–0.995)*
Smoking status (ref: Never smoked)		
Former smoker	0.62 (0.445–0.867)**	0.62 (0.445–0.867)**
Current smoker	0.53 (0.316–0.896)*	0.53 (0.316–0.895)*
Alcohol status (ref: Non-drinker)		
Former drinker	1.14 (0.823–1.580)	1.14 (0.823–1.584)
Current drinker	1.10 (0.798–1.512)	1.10 (0.797–1.513)
Regular physical activity (ref: No)		
Yes	0.67 (0.536–0.845)***	0.67 (0.536–0.845)***
Self-rated health (ref: Good)		
Fair	1.29 (0.999–1.673)†	1.29 (0.997–1.674)†
Poor	1.42 (1.020–1.966)*	1.42 (1.023–1.967)*
Instrumental activities of daily living	1.07 (1.003–1.131)*	1.07 (1.003–1.132)*
†$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$		

Figures

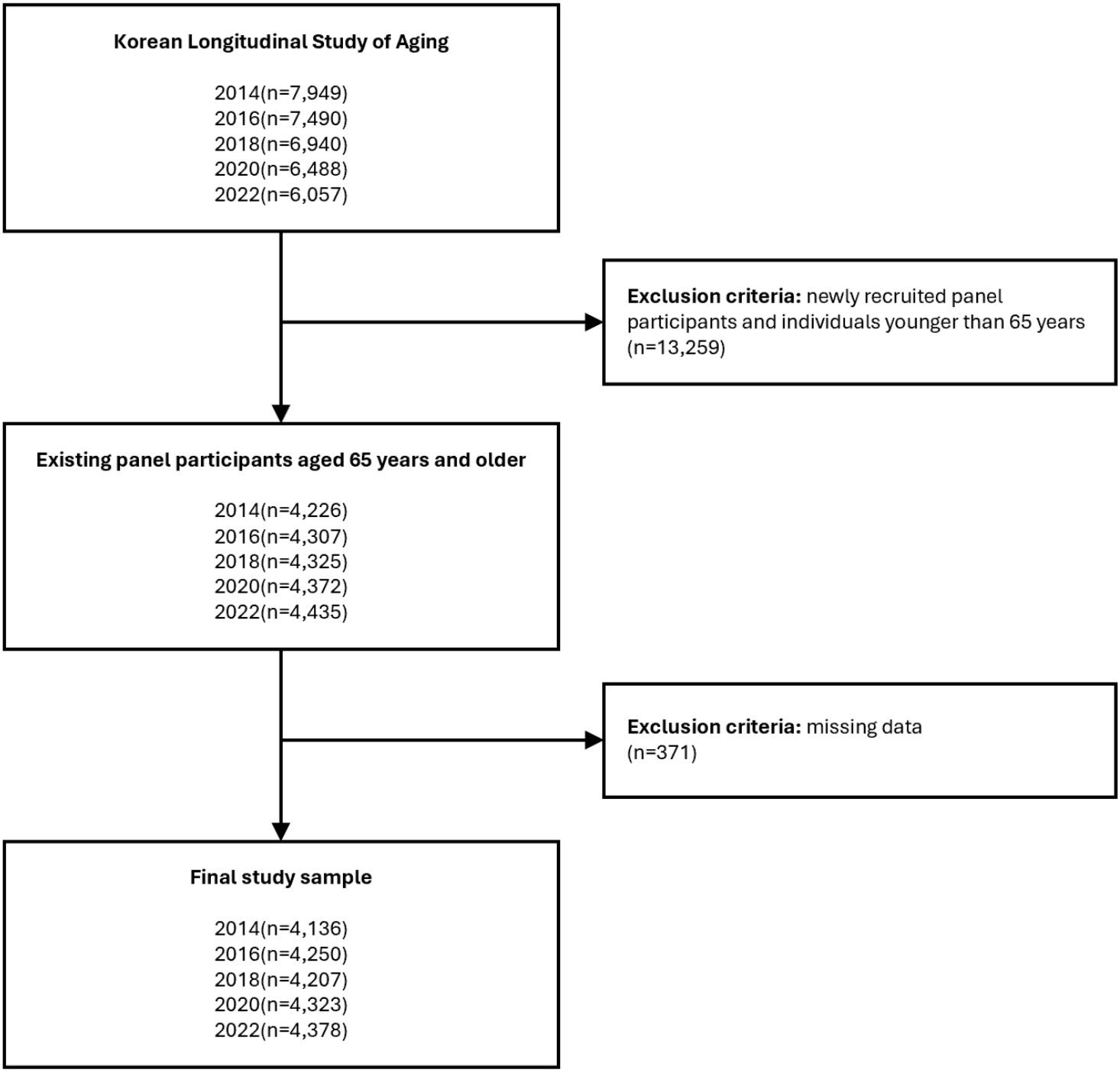


Figure 1

Flowchart of study sample selection from the Korean Longitudinal Study of Aging

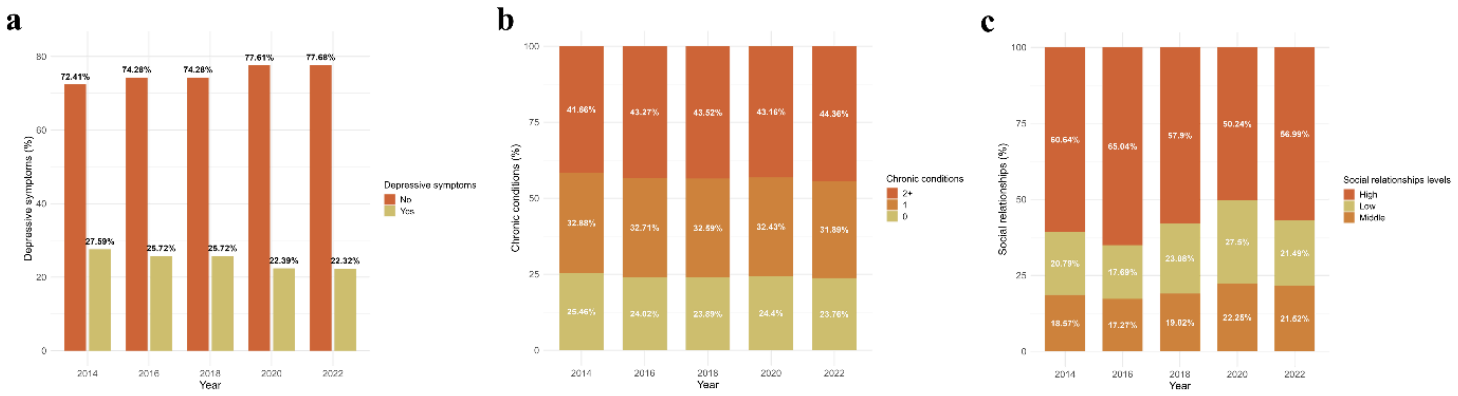


Figure 2

Trends in (a) depressive symptoms, (b) chronic conditions, and (c) social relationships among older adults, 2014–2022.

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