ORIGINAL ARTICLE
https://doi.org/10.30773/pi.2022.0303
Print ISSN 1738-3684 / On-line ISSN 1976-3026
OPEN ACCESS

Social Connectedness and Cognitive Function Before and During COVID-19: A Longitudinal Study of Korean Older Adults With an Instrumental Variable Regression

Jungtaek Lee[1] and Juyeon Kim[2] ✉

[1]Department of Economics, Dongguk University, Seoul, Republic of Korea
[2]Department of Urban Sociology, University of Seoul, Seoul, Republic of Korea

Objective We estimate the causal effect of social connectedness (i.e., the frequencies of meeting with friends, relatives, or neighbors) on cognitive function (the Korean version of Mini-Mental State Exam) among Korean older adults.

Methods We used longitudinal panel data collected before and during the coronavirus disease-2019 (COVID-19) to set up the fixed (FE) or random effect (RE) models. To overcome omitted variable bias or reverse causality, we used COVID-19 pandemic period as an instrumental variable to estimate the causal effect of social connectedness on cognitive function.

Results Social distancing measures during the COVID-19 period decreased social interaction. The results showed that an increase in the frequency of social interaction led an increase in cognitive scores. Specifically, an increase of one unit in the frequency of meeting familiar people increased cognitive scores by 0.1470 and 0.5035 in the RE and FE models, respectively.

Conclusion Social distancing policies due to the global pandemic may have increased the risk of social isolation and cognitive decline among older adults. The government and local communities need to increase their effort to develop way to connect adults through the remainder of the pandemic and beyond.

Psychiatry Investig 2023;20(4):325-333

Keywords Cognitive function; Social connectedness; COVID-19; Social distancing.

INTRODUCTION

South Korea is one of the fastest aging countries in the world.[1] While it took 114 years for France's population aged 65 or older to rise from 7% (aging society) to 14% (aged society) and 24 years for Japan's, it took only 19 years for South Korea.[2] Consequently, increased burden on dementia care were already at the forefront of public health concerns. In 2020, the total number of Korean adults aged 65 or older was 8,134,675; of these, the estimated number of dementia patients was 840,191, thus reaching a prevalence rate of dementia of 10.33%. The nationwide estimated cost of managing dementia was 18.7198 trillion won, about 21.24 million won per person.[3] Protecting cognitive function in later life is an important prerequisite for healthy aging, and social connectedness is one of the crucial modifiable risk factors.[4] However, social distancing policies due to the global pandemic may have increased the risk of social isolation of older adults, who are already at the risk of reduced social connectedness during the aging process.[5]

Since the first case of coronavirus disease-2019 (COVID-19) was reported on January 20, 2020, South Korea was able to flatten the epidemic curve quickly without closing businesses, implementing many of the stricter measures such as issuing stay-at-home orders, avoiding mass gatherings, closure and delayed opening of schools and day care centers, adopted by other high-income countries until late 2020.[6] However, these social distancing measures for preventing the spread of the virus may have had unintended consequences. Studies have shown that a wide range of social distancing measures is closely related to having fewer social contacts and less engagement in social activities, which in turn influence mental health.[7-17]

Even before the pandemic, social isolation has been shown to affect many aspects of both mental and physical health[18,19]

Received: October 27, 2022 **Revised:** January 8, 2023
Accepted: January 15, 2023

✉ **Correspondence:** Juyeon Kim, PhD
Department of Urban Sociology, University of Seoul, 163 Seoulsiripdae-ro, Dongdaemun-gu, Seoul 02504, Republic of Korea
Tel: +82-2-6490-2745, **Fax:** +82-6490-2734, **E-mail:** juykim@uos.ac.kr

as well as cognitive function.[20] While good health is a prerequisite for high quality of life, good cognitive function is a key determinant of quality of life and independence among older adults.[21] Previous studies have already highlighted how social isolation[20,22,23] and loneliness[24-27] can be detrimental for cognitive functioning, particularly among older adults, as they are more at risk of losing social connectedness.[28-30] Hypotheses on the mechanisms by which social relationships can reduce cognitive decline include: delay of cognitive atrophy ("use it or lose it"),[31] higher cognitive reserve,[32] and preventing stress-related cognitive declines.[22] As such, a myriad of studies has highlighted the importance of social connectedness and preventing social isolation in later life. While aging is generally associated with increased risk of social isolation,[5] forced social distancing after COVID-19 may have exacerbated social isolation among older adults, which can in turn affect cognitive function. Despite the increased risk of social isolation after COVID-19, there has been a scarcity of literature focusing on the cognitive function of older adults. Therefore, the purpose of study is to test whether the association between social isolation and cognitive function among older adults has changed between before and during the COVID-19 period by using the Korean Longitudinal Study of Aging (KLoSA).

However, it is difficult to empirically estimate the causal effect of social isolation on cognitive function. For example, individuals with poor social networks are likely to have distinct characteristics from those who have good social networks. Differences in observed or unobserved characteristics may thus lead to different cognitive functioning between the two groups. Differences in cognitive function may also be caused by unobservable factors other than social networks (omitted variable bias).[33] Moreover, social networks are expected to influence cognitive function, but reversely, cognitive decline may also be a cause of poor social networks rather than a consequence (reverse causality).[28,30] To overcome omitted variable bias or reverse causality bias, we use instrumental variable (IV) regression to estimate the effect on cognitive function through two-stage least squares (2SLS) regression. Assessing cognitive decline caused by social distancing during the COVID-19 pandemic provides an opportunity to create a quasi-experimental research design in that social networks for all individuals were influenced by social distancing during the pandemic. Thus, we can estimate the causal effect of social isolation on cognitive function.

While COVID-19 is the global pandemic and many countries have implemented social distancing, Korea was one of the first countries to be hit by the COVID-19 and experienced the sharp increase in the confirmed cases when the highly concentrated local transmission was detected in Daegu on February 19, 2020. Korea government immediately declared Daegu as management zones and implemented strict nationwide social distancing policies from the very early period.[34] These changes provide quasi-experimental setting to estimate the causal effect of social isolation (connectedness) on cognitive function.

This study contributes to the literature on estimating the effect of social isolation on cognitive function by addressing omitted variable bias or reverse causality. To our knowledge, this study is the first to estimate the causal effect of social isolation (connectedness) on cognitive function using the COVID-19 period as an IV.

METHODS

Data

We used data from the KLoSA, a nationally representative longitudinal survey of non-institutionalized Koreans 45 years old or older.[35] To allow for international comparative studies on population ageing, the survey categories and topics have been drafted in reference to the US, UK, and European versions of the panel study: Health and Retirement Study, English Longitudinal Study of Ageing, Survey of Health, and Ageing and Retirement in Europe. A basic survey has been conducted every other year, and the present study uses the sample period from 2016 to 2020, which consists of three waves of the survey. The baseline sample included 7,746 respondents. Because Seoul and adjacent Gyeongi province have had higher number of cumulative confirmed cases per 1,000 than other regions due to higher population density and Daegu and the adjacent Gyeongbuk province had the first large outbreak of the COVID-19 on February 2020, our analytic sample was restricted to those respondents who resided in the four regions of Seoul, Gyeongi, Deagu, and Gyeongbuk. We also excluded those respondents who had missing values on social isolation and cognitive function, thus resulting in a final sample size of 7,746. The sample in this study is split into two periods: before and after COVID-19. To consider how the COVID-19 pandemic has influenced social isolation and cognitive function, the sample period includes time covering the COVID-19 pandemic. The KLoSA was designed to provide information regarding family, health status, economic status, and health behavior. Specifically, variables measuring cognitive function and social isolation are collected. Table 1 provides the summary statistics for the outcome variables and control variables. This study was approved by the Institutional Review Board of University of Seoul (IRB number: 2022-10-004).

Measures

Social connectedness (social isolation)

Social connectedness was measured by the frequencies of social interactions, i.e., the frequency of meeting with friends, relatives, or neighbors. They were drawn from the survey question in the KLoSA: "How often do you meet friends or relatives in person?" We recoded respondent's answers as the number of meetings per month. Table 1 presents the average number of meetings with friends or relatives in person per

Table 1. Basic statistics before and after COVID-19

Variables	Before COVID-19		After COVID-19		t-test stat (p)
	Number	Mean or percentage	Number	Mean or percentage	
Gender					-0.4034 (0.6866)
Male	2,250	42.1%	1,002	41.6%	
Female	3,090	57.9%	1,404	58.4%	
Age (yr)	5,340	69.3	2,406	71.4	-8.5881 (<0.0001)***
Marital status					1.5806 (0.1140)
Married	4,025	75.4%	1,773	73.7%	
Education					-0.7934 (0.4275)
Dropout	2,719	50.9%	1,191	49.5%	
High school grad	1,835	34.4%	861	35.8%	
College or above	786	14.7%	354	14.7%	
Labor status					-3.2046 (0.0014)***
Employed	1,911	35.8%	771	32.0%	
Unemployed	3,429	64.2%	1,635	68.0%	
Family income, unit: 1,000 won	5,340	3,399	2,406	3,754	-3.5154 (0.0004)***
Drinking status					3.1468 (0.0017)**
Currently drinker	1,743	32.6%	699	29.1%	
Former drinker, non-drinker	3,597	67.4%	1,707	71.0%	
Smoking status					-0.2037 (0.8386)
Currently smoker	1,526	28.6%	693	28.8%	
Former smoker, non-smoker	3,814	71.4%	1,713	71.2%	
Self-rated health					0.8123 (0.4166)
Very good	48	0.9%	27	1.1%	
Good	1,208	22.6%	444	18.5%	
Normal	2,462	46.1%	1,291	53.7%	
Bad	1,248	23.4%	519	21.6%	
Very bad	374	7.0%	125	5.2%	
Chronic disease					-3.2682 (0.0011)**
No	505	9.5%	173	7.2%	
Yes	4,835	90.5%	2,233	92.8%	
Region					-0.8556 (0.3923)
Metropolitan	2,792	52.3%	1,224	50.9%	
City	1,965	36.8%	919	38.2%	
Town	583	10.9%	263	10.9%	
Frequency of meeting with friends, relatives, and neighbors (mo)	5,340	5.54	2,406	4.54	6.8126 (<0.0001)***
MMSE, score: 0−30	5,340	25.5	2.232	25.1	2.6947 (0.0071)*

*p<0.05; **p<0.01; ***p<0.001. COVID-19, coronavirus disease-2019; MMSE, Mini-Mental State Exam

month before and after COVID-19. The average number of meetings with friends, relatives, or neighbors in person per month decreased from 5.54 to 4.54.

Cognitive function

The KLoSA includes the Korean version of Mini-Mental State Exam (K-MMSE) as a measure of global cognitive function. The K-MMSE consists of 11 items in seven categories including items measuring orientation in time, space, and person, registration of three objects, attention, and calculation, recall of three words, language, and visual construction. Scores on the K-MMSE range from 0 to 30, with higher scores indicating higher cognitive functioning. A K-MMSE score of 24 or more was regarded as being indicative of normal cognitive functioning.

Covariates

The analyses were adjusted for a range of demographic variables, such as age, gender (male=0, female=1), marital status (others=0, married=1), educational attainment (dropout=0, high school or less education=1, high school grad=2, some college=3, a bachelor's degree or more=4), area of residence (metropolitan=0, city and town=1), employment status (currently employed=0, unemployed=1), and household income. Household income was included in the analysis as a log transformation. In addition to basic sociodemographic variables, we also considered health-related covariates that could affect the outcome variables (social isolation and cognitive function): smoking status (current smoker=1), alcohol use (current drinker=1), and self-rated health.

Analysis

To better understand how the COVID-19 period has influenced social connectedness and cognitive function, we compare outcome variables before and during COVID-19. Basically, we attempted to control for time-constant unobserved characteristics to estimate the causal effect of the variable of interest. This study used panel data to set up fixed or random effect (RE) models. The fixed effect (FE) model is an appropriate specification if there are correlations between control variables and error terms. Further, to control for time-invariant unobserved characteristics, we use IV regression (2SLS). For example, those with less social contacts may be statistically different in terms of demographic characteristics from those with relatively higher social contacts. A wider range of characteristics related to social connectedness may also be related to cognitive function, which in turn leads to biased estimators. The COVID-19 pandemic provides a randomly chosen group of people with less social contacts as a result of social distancing measures compared to the sample before the pandemic. Thus, we assign the pandemic period, which is the year 2020, as an IV for social isolation to consider the causal relationship between social isolation and cognitive function.

To show how IV regression can solve the omitted variable bias, we first use the following cross-sectional equation to measure the effect of social isolation on cognitive function (structural equation).

$$Y_{it}=X'_{it}\alpha_0+\beta_1 SC_{it}+\varepsilon_{1it}, \quad (1)$$

where Y_{it} is respondent i's cognitive score in year t, and SC_{it} is i's frequency of social interaction per month. X_{it} is a vector of i's demographic characteristics in year t. Suppose that unobserved characteristics impact both social isolation and cognitive function. Without additional information, the parameter of interest β_1 cannot be identified. If an IV, denoted Z_{it}, exists, then the identifying assumption is that (1) Z_{it} is uncorrelated with the omitted variable in the error term and (2) Z_{it} is correlated with social connectedness. Then, an IV estimate of social connectedness is the sample analogue of $Cov(Y_{it}, Z_{it})/Cov(SC_{it}, Z_{it})$. Thus, the first stage and reduced form are as follows:

$$SC_{it}=X'_{it}\alpha_2+\beta_2 Z_{it}+\varepsilon_{2it}, \quad (2)$$

$$Y_{it}=X'_{it}\alpha_3+\beta_3 Z_{it}+\varepsilon_{3it}. \quad (3)$$

The coefficient of interest is the ratio of population regression of Y_{it} on Z_{it}, which is called the reduced form (3), to the population regression of $SC_{it}(CESD_{it})$ on Z_{it}, the first stage (2).

RESULTS

Table 1 lists the descriptive statistics for the sample before and after the COVID-19 period (2016, 2018 vs. 2020). Of all older adults aged 50 or over, proportions of male and female, marital status, educational attainments, smoking status, self-rated health, and regions are not statistically different between before and after COVID-19. However, the mean differences of age, working status, family income, drinking status, chronic illness status, social connectedness (frequency of meeting with friends, relatives, or neighbors), and cognitive function are all statistically significant at the conventional levels. This implies that older adults' socioeconomic or health-related status may have changed during COVID-19 compared to before the COVID-19 outbreak. Given the fact that distinct characteristics between before and after the COVID-19 can be correlated with both social connectedness and cognitive function, unobservable characteristics may also influence them, which would in turn lead to a biased estimator in Eq. (1).

Table 2. Relationships between social connectedness and cognitive function (structural models) (N=2,792)

	Cognitive score (MMSE)	
	OLS regression	
	(1) Random effect [SE]	(2) Fixed effect [SE]
Frequency of meeting with friends, relatives or neighbors per month	0.0926 [0.0079]***	0.0286 [0.0093]***
Age (yr)	-0.2161 [0.0089]***	-0.2369 [0.0222]***
Married	0.8184 [0.1705]***	0.9044 [0.3553]**
Gender, female	-1.0572 [0.2110]***	-
Education		
Dropout	(Base)	(Base)
Highschool grad	0.9182 [0.1724]***	-0.4706 [0.6423]
College grad or above	1.1355 [0.2320]***	1.3844 [1.0926]
Unemployed	-0.1319 [0.1315]	-0.0403 [0.1666]
Log, household income	0.0382 [0.0529]	0.1908 [0.0667]***
Region		
Metropolitan	(Base)	(Base)
City	0.3975 [0.4155]	0.7020 [0.5403]
Town	0.6209 [0.4129]	0.0824 [0.5871]
Drinking status	0.2462 [0.1474]*	0.6238 [0.2303]***
Smoking status	-0.1465 [0.2049]	0.3951 [0.7632]
Self-rated health		
Very good	(Base)	(Base)
Good	1.0684 [0.4065]***	1.0194 [0.4328]**
Normal	0.8297 [0.4056]**	0.9256 [0.4333]**
Bad	-0.1578 [0.4172]	0.3602 [0.4484]
Very bad	-3.4180 [0.4549]***	-1.9205 [0.4962]***
Existence of chronic disease	0.2567 [0.2354]	0.2049 [0.4006]
Hausman test	357.23***	
Observation	7,249	7,249

All statistics are based on a dataset created by the Korean Longitudinal Study of Aging for 2016–2020. *p<0.05; **p<0.01; ***p<0.001. OLS, ordinary least squares; SE, standard error; MMSE, Mini-Mental State Exam

Table 2 shows results from estimating Eq. (1) without an IV, which is the COVID-19 period. Table 2 also presents both RE and FE estimates of the effect of social connectedness on cognitive function. The results of the RE and FE models suggest that an increase of one unit in frequency of meeting with familiar people such as friends, relatives, or neighbors leads to an increase of 0.0926 or 0.0286 in cognitive function, respectively. However, since these results can be biased estimators caused by omitted variable bias or reverse causality, we use an IV, the COVID-19 period (year 2020), to estimate the causal effect of social connectedness on cognitive function.

To estimate the causal effect, we first estimate the effect of the COVID-19 on social connectedness using the first-stage Eq. (1). For the identification of the model, an IV closely related to social connectedness should be used. As shown in columns (1) and (2) of Table 3, during the COVID-19 pandemic, the frequency of social meeting was reduced relative to periods before the COVID-19. The frequency of meeting with friends, relatives, or neighbors per month decreased by 1.12 or 0.57 depending on the specifications. Consistent with the previous studies, social distancing measures during the COVID-19 period may have decreased social interaction. However, Hausman tests statistics suggest that time-constant unobserved characteristics are correlated with a main variable of interest: the frequency of social interaction. Thus, the FE model is preferred to the RE estimator.

Secondly, columns (3) and (4) of Table 3 report the results of the reduced form regression regarding the effect of the COVID-19 on cognitive function. The results suggest that cognitive scores declined during the COVID-19. In the RE model, the cognitive score decreased by 0.1190, but the coefficient was not statistically significant. However, the coefficient on the FE model was statistically significant, which implies that the cognitive scores decreased by 0.3131 during the COVID-19 period. Since the Hausman test implies that the coefficients between the RE and FE models are statistically different, the FE model should also be preferred in the reduced form regression. In addition, results indicate that education contributes to higher cognitive scores and better self-rated health is closely related with better cognitive performance. Those who rated their health as very bad have lower cognitive scores by 3.57 relative to those who rated self-rated health as very good.

Thirdly, Table 4 presents the results of the second stage least square regression which is an IV estimator. To control for unobserved heterogeneities that influence both the frequency of social meeting with and cognitive function, we use the year 2020 as an IV to estimate the causal effect of the frequency of social interaction on cognitive function. Columns (1) and (2) show the causal effect of social connectedness on cognitive

Table 3. Effects of COVID-19 on social connectedness (first-stage and reduced-form regressions)

	Frequency of meeting with familiars per month		Cognitive score (MMSE)	
	(1) Random effect [SE]	(2) Fixed effect [SE]	(3) Random effect [SE]	(4) Fixed effect [SE]
COVID-19	-1.1205 [0.1163]***	-0.5651 [0.2212]**	-0.1190 [0.0767]	-0.3131 [0.1407]**
Age (yr)	0.0366 [0.0114]***	-0.1797 [0.0644]***	-0.2128 [0.0095]***	-0.1690 [0.0410]***
Gender, female	0.9578 [0.2526]***	-	-0.9582 [0.2181]***	-
Married	-0.6440 [0.2132]***	-0.1442 [0.5477]	0.7684 [0.1749]***	0.8917 [0.3555]**
Education				
Dropout	(Base)	(Base)	(Base)	(Base)
Highschool grad	-0.2509 [0.2102]	0.0641 [0.9480]	0.4092 [0.4201]	-0.4809 [0.6427]
College grad or above	-0.7179 [0.2803]***	-0.7675 [1.6139]	0.7597* [0.4183]	1.3015 [1.0933]
Unemployed	-0.0937 [0.1823]	-0.1325 [0.2629]	-0.1343 [0.1327]	-0.0366 [0.1667]
Log, household income	-0.2061 [0.0729]***	-0.0923 [0.1005]	0.0342 [0.0538]	0.1919 [0.0667]***
Region				
Metropolitan	(Base)	(Base)	(Base)	(Base)
City	-1.0074 [0.5833]*	1.6460 [0.8494]*	0.4092 [0.4201]	0.7333 [0.5404]
Town	1.1199 [0.5686]**	1.0010 [0.9148]	0.7597 [0.4183]*	0.0371 [0.5886]
Drinking status	0.2628 [0.1919]	0.5955 [0.3541]*	0.2929 [0.1501]*	0.6382 [0.2303]***
Smoking status	-0.2475 [0.2460]	0.6715 [1.2105]	-0.1601 [0.2119]	0.4630 [0.7638]
Self-rated health				
Very good	(Base)	(Base)	(Base)	(Base)
Good	-0.2476 [0.6129]	-0.0433 [0.6860]	1.0325 [0.4057]**	1.0110 [0.4330]**
Normal	-0.5566 [0.6108]	0.2123 [0.6884]	0.7973 [0.4048]**	0.9381 [0.4335]**
Bad	-0.9423 [0.6265]	-0.2783 [0.7114]	-0.2109 [0.4167]	0.3424 [0.4486]
Very bad	-3.2194 [0.6674]***	-1.8359 [0.7747]**	-3.5716 [0.4546]***	-1.9951 [0.4964]***
Existence of chronic disease	0.0215 [0.3032]	0.2842 [0.6286]	0.2664 [0.2408]	0.2107 [0.4008]
Hausman test	109.77***		216.05***	
Observation	7,743 [2,882]	7,743 [2,792]	7,249 [2.792]	7,249 [2,792]

All statistics are based on a dataset created by the Korean Longitudinal Study of Aging for 2016–2020. *p<0.05; **p<0.01; ***p<0.001. COVID-19, coronavirus disease-2019; SD, standard error; MMSE, Mini-Mental State Exam

function, which indicates that an increase in the frequency of social interaction leads to an increase in cognitive scores in both RE and FE models. Specifically, an increase of one unit in the frequency of meeting familiar people increases cognitive scores by 0.1470 and 0.5035 depending on the specifications. However, a statistic for the Hausman test implies that the difference in the coefficients between the RE and FE models is not statistically significant. Thus, the coefficients in the RE model are considered to be more efficient than those in the FE model. Based on the results of the RE model, an increase in social connectedness increased the cognitive score. Compared to the results of structural models without an IV, IV estimators, coefficients on 2SLS models, are greater than those on structural models. IV estimators in Table 4 can be larger than the ordinary least squares (OLS) estimators in Table 2. While OLS estimators indicate the average treatment effect over the whole population, IV estimators imply the local average treatment effect, which estimates the effect of only for the population who changed their social connectedness by social distancing during the COVID-19. Therefore, the coefficients in Table 2 are likely to be smaller than coefficients in Table 4.

Finally, to be a valid instrument, an instrument variable must further satisfy the exclusion restriction, which implies that social distancing has an effect on cognitive function only through its effect on social connectedness. Social distancing caused by the COVID-19 may have influenced several factors, which in turn affected cognitive function. Marital status, employment status, smoking or drinking status, or health status can all be related to cognitive function. Previous studies have concluded that there are several factors that affect cognitive function.[36-40] Thus, for robustness, we test whether there are other pathways through which cognitive function is influenced. Supplementary Table 1 (in the online-only Data Sup-

Table 4. Effects of social connectedness on cognitive function (two-stage least squares) (N=2,792)

	Cognitive score (MMSE)	
	(1) Random effect [SE]	(2) Fixed effect [SE]
Frequency of meeting with familiars per month	0.1470 [0.0677]**	0.5035 [0.2853]*
Age (yr)	-0.2149 [0.0149]***	-0.0880 [0.0936]
Gender, female	-0.9584 [0.3889]**	-
Married	0.9344 [0.2399]***	1.0252 [0.4539]**
Education		
Dropout	(Base)	(Base)
Highschool grad	0.6434 [0.3024]**	-0.6972 [0.8214]
College grad or above	1.2098 [0.4332]***	1.8975 [1.4120]
Unemployed	-0.0688 [0.1330]	-0.0352 [0.2102]
Log, household income	0.1781 [0.0546]***	0.2161 [0.0855]**
Region		
Metropolitan	(Base)	(Base)
City	0.4792 [0.4313]	-0.2441 [0.8870]
Town	0.1946 [0.4589]	-0.6818 [0.8710]
Drinking status	0.4522 [0.1772]**	0.3458 [0.3350]
Smoking status	-0.0111 [0.3547]	-0.1035 [1.0080]
Self-rated health		
Very good	(Base)	(Base)
Good	1.0428 [0.3589]***	1.1571 [0.5520]**
Normal	0.8919 [0.3589]**	0.9016 [.05467]*
Bad	0.2701 [0.3717]	0.5716 [0.5796]
Very bad	-2.1076 [0.4237]***	-1.1488 [0.7786]
Existence of chronic disease	0.1932 [0.2907]	-0.0023 [0.5203]
Hausman test	8.97	
Observation	7,249	7,249

All statistics are based on a dataset created by the Korean Longitudinal Study of Aging for 2016–2020. *p<0.05; **p<0.01; ***p<0.001. MMSE, Mini-Mental State Exam; SE, standard error

plement) shows that these are not likely to be potential mechanisms in this study. Risky behaviors, such as smoking and drinking status, did not change between before and during COVID-19. Moreover, social distancing during COVID-19 did not affect marital status, employment status, or self-rated health status among older adults in Korea compared to before COVID-19.

DISCUSSION

The association between social connectedness and cognitive function is likely a bidirectional relationship, where cognitive decline can lead to altered social relationships.[41-43] To overcome omitted variable bias or reverse causality, this study used the COVID-19 period as a natural experiment and used an IV to estimate how social interaction influenced cognitive function. Those who have low social connectedness are likely to be different from those who have more social connectedness in a wider range of observed and unobserved characteristics, which may be related to cognitive function. Further, this leads to biased estimates. Thus, we assigned the pandemic period as an IV for social connectedness to consider the causal relationship between social connectedness and cognitive function. We used the longitudinal panel data collected before and during the COVID-19, KLoSA, which comprises data that are comparable to the Health and Retirement Study in the US as well as the English Longitudinal Study of Ageing.

First, the frequency of socializing with friends, relatives, or neighbors was reduced during COVID-19. Although this decrease in objective social connectedness was an expected finding after the Korean government implemented strict social distancing, our finding is the first study to confirm that social connectedness was actually reduced using nationally represented data collected before and during COVID-19.

Second, and more surprisingly, our finding shows that the cognitive function of those aged 50 and older has significantly reduced during COVID-19. One possible explanation for this finding is that unwanted and prolonged social distancing severely obstruct basic human needs, such as those for social contact, affiliation, affection, and support,[44] which may increase overall stress level and undermining cognitive function. Alternatively, this finding may support previous findings that social networks are a source of cognitive stimulation whereby such sudden and prolonged restriction in everyday social interactions could have significantly reduced cognitive stimuli, leading to a decline in cognitive function even within a relatively short term. Further studies are needed to understand the mechanism of this sharp decrease in cognitive function within just two years, but as a response to address the immediate needs around social disconnectedness and cogni-

tive decline, several virtual adaptations for older adults have now been developed. For instance, Zubatsky[45] describes Cognitive Stimulation Therapy, Circle of Friends that have been effective in in-person settings and are transitioned to virtual delivery during the pandemic. These virtual versions of programs could be effective in virtual settings provided they were appropriately retrofitted. The government and local communities, therefore, need to increase their effort to develop way for providers and community partners to establish groups to connect adults through the remainder of the pandemic and beyond.

Third, some changes in covariates in the descriptive statistics need to be noted. Family income has been reduced and the proportion of unemployment among those aged 50 and over has been increased. In other words, the economic status of those aged 50 and over has worsened during COVID-19. The average replacement rate of pension benefits, which is the ratio of pension benefits to pre-retirement average earnings, is currently 40%.[46] In fact, one in three older adults work for pay, but most of them work in low paying, unstable, and non-regular jobs (e.g., temporary or day labor), which do not provide sufficient income.[47] With a lower replace rate of pension benefits and increased unemployment, COVID-19 could have increased the poverty rate of Korean older adults, which was already exceptionally high among OECD average of 13.5%.[46] Although some local governments and communities have taken steps to include daily phone calls, home visits, online care programs, meal delivery services, and GPS tracking for cognitively impaired older adults to fill the gap, further monitoring and interventions strategies are need to meet increased financial and caring needs.

Another noteworthy finding is that drinking has increased during COVID-19. It is not clear whether drinking "alone" or drinking "with others to compensate outdoor activities" have increased, but since binge drinking is one of the risk factors for dementia,[3] alcohol consumption behavior need to be monitored.

This study has some limitations. First, the results in this study are derived from a relatively short sample period. Given that the pandemic persists, we only considered the early stage of the pandemic including the year 2020. If the sample period were extended, older adults' behavior or status might have exhibited different patterns. Second, the results are based on the longitudinal representative sample of Korean older adults. Therefore, it is not clear whether the results can represent older adults across the world. Despite these limitations, this study is the first to estimate the causal effect of social connectedness on cognitive function using the COVID-19 pandemic period as an IV. The results from 2SLS using an IV show that the magnitude of the estimator in simple OLS can be overestimated if omitted variable bias or reverse causality is not considered. To consider another mechanism by which cognitive function can be influenced during the pandemic, we also consider the effect of the COVID-19 on other factors such as smoking, drinking, and marital status, which may influence cognitive function. Potential factors other than social contact or depressive symptoms during the pandemic are not influenced by the COVID-19 pandemic.

Supplementary Materials

The online-only Data Supplement is available with this article at https://doi.org/10.30773/pi.2022.0303.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Jungtaek Lee, Juyeon Kim. Data curation: Jungtaek Lee. Formal anslysis: Jungtaek Lee. Investigation: Jungtaek Lee. Methodology: Jungtaek Lee. Software: Jungtaek Lee. Validation: Jungtaek Lee, Juyeon Kim. Writing—original draft: Jungtaek Lee, Juyeon Kim. Writing—reveiw & editing: Jungtaek Lee, Juyeon Kim.

ORCID iDs

Jungtaek Lee https://orcid.org/0000-0003-3514-4250
Juyeon Kim https://orcid.org/0000-0001-6797-8271

Funding Statement

None

REFERENCES

1. United Nations, Department of Economics and Social Affairs, Population Division. World population ageing 2019: highlights. New York: United Nations; 2019.
2. World Health Organization. Global health and aging. Geneva: World Health Organization; 2011.
3. Lee J, Kang MJ, Lee OJ, Kwak MY, Seo JW, Ko IS. Korean dementia observatory 2021. Seoul: National Institute of Dementia; 2022.
4. Livingston G, Sommerlad A, Orgeta V, Costafreda SG, Huntley J, Ames D, et al. Dementia prevention, intervention, and care. Lancet 2017;390:2673-2734.
5. Umberson D, Lin Z, Cha H. Gender and social isolation across the life course. J Health Soc Behav 2022;63:319-335.
6. Kim J, An A, Oh SJ, Oh J, Lee J. Emerging COVID-19 success story: South Korea learned the lessons of MERS [Internet]. Available at: https://ourworldindata.org/covid-exemplar-south-korea. Accessed January 8, 2023.
7. Heidinger T, Richter L. The effect of COVID-19 on loneliness in the elderly. An empirical comparison of pre-and peri-pandemic loneliness in community-dwelling elderly. Front Psychol 2020;11:585308.
8. van Tilburg TG, Steinmetz S, Stolte E, van der Roest H, de Vries DH. Loneliness and mental health during the COVID-19 pandemic: a study among Dutch older adults. J Gerontol B Psychol Sci Soc Sci 2021;76:e249-e255.
9. Krendl AC, Perry BL. The impact of sheltering in place during the COVID-19 pandemic on older adults' social and mental well-being. J

Gerontol B Psychol Sci Soc Sci 2021;76:e53-e58.
10. Luchetti M, Lee JH, Aschwanden D, Sesker A, Strickhouser JE, Terracciano A, et al. The trajectory of loneliness in response to COVID-19. Am Psychol 2020;75:897-908.
11. Folk D, Okabe-Miyamoto K, Dunn E, Lyubomirsky S. Did social connection decline during the first wave of COVID-19?: the role of extraversion. Collabra Psychol 2020;6:37.
12. Peng S, Roth AR. Social isolation and loneliness before and during the COVID-19 pandemic: a longitudinal study of U.S. adults older than 50. J Gerontol B Psychol Sci Soc Sci 2022;77:e185-e190.
13. Choi EY, Farina MP, Wu Q, Ailshire J. COVID-19 social distancing measures and loneliness among older adults. J Gerontol B Psychol Sci Soc Sci 2022;77:e167-e178.
14. Brooke J, Jackson D. Older people and COVID-19: isolation, risk and ageism. J Clin Nurs 2020;29:2044-2046.
15. Holmes EA, O'Connor RC, Perry VH, Tracey I, Wessely S, Arseneault L, et al. Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science. Lancet Psychiatry 2020;7:547-560.
16. Liu CH, Zhang E, Wong GTF, Hyun S, Hahm HC. Factors associated with depression, anxiety, and PTSD symptomatology during the COVID-19 pandemic: clinical implications for U.S. young adult mental health. Psychiatry Res 2020;290:113172.
17. Vahia IV, Jeste DV, Reynolds CF 3rd. Older adults and the mental health effects of COVID-19. JAMA 2020;324:2253-2254.
18. Holt-Lunstad J, Smith TB, Baker M, Harris T, Stephenson D. Loneliness and social isolation as risk factors for mortality: a meta-analytic review. Perspect Psychol Sci 2015;10:227-237.
19. Shor E, Roelfs DJ. Social contact frequency and all-cause mortality: a meta-analysis and meta-regression. Soc Sci Med 2015;128:76-86.
20. Evans IEM, Martyr A, Collins R, Brayne C, Clare L. Social isolation and cognitive function in later life: a systematic review and meta-analysis. J Alzheimers Dis 2019;70(S1):S119-S144.
21. Abud T, Kounidas G, Martin KR, Werth M, Cooper K, Myint PK. Determinants of healthy ageing: a systematic review of contemporary literature. Aging Clin Exp Res 2022;34:1215-1223.
22. Fratiglioni L, Paillard-Borg S, Winblad B. An active and socially integrated lifestyle in late life might protect against dementia. Lancet Neurol 2004;3:343-353.
23. Kelly ME, Duff H, Kelly S, McHugh Power JE, Brennan S, Lawlor BA, et al. The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: a systematic review. Syst Rev 2017;6:259.
24. Cacioppo JT, Hawkley LC. Perceived social isolation and cognition. Trends Cogn Sci 2009;13:447-454.
25. O'Luanaigh C, O'Connell H, Chin AV, Hamilton F, Coen R, Walsh C, et al. Loneliness and cognition in older people: the Dublin healthy ageing study. Aging Ment Health 2012;16:347-352.
26. Tilvis RS, Kähönen-Väre MH, Jolkkonen J, Valvanne J, Pitkala KH, Strandberg TE. Predictors of cognitive decline and mortality of aged people over a 10-year period. J Gerontol A Biol Sci Med Sci 2004;59:268-274.
27. Wilson RS, Krueger KR, Arnold SE, Schneider JA, Kelly JF, Barnes LL, et al. Loneliness and risk of Alzheimer disease. Arch Gen Psychiatry 2007;64:234-240.
28. Aartsen MJ, Van Tilburg T, Smits CH, Knipscheer KC. A longitudinal study of the impact of physical and cognitive decline on the personal network in old age. J Soc Pers Relatsh 2004;21:249-266.
29. Cornwell EY, Waite LJ. Social disconnectedness, perceived isolation, and health among older adults. J Health Soc Behav 2009;50:31-48.
30. Steptoe A, Shankar A, Demakakos P, Wardle J. Social isolation, loneliness, and all-cause mortality in older men and women. Proc Natl Acad Sci U S A 2013;110:5797-5801.
31. Hultsch DF, Hertzog C, Small BJ, Dixon RA. Use it or lose it: engaged lifestyle as a buffer of cognitive decline in aging? Psychol Aging 1999;14:245-263.
32. Bennett DA, Schneider JA, Tang Y, Arnold SE, Wilson RS. The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: a longitudinal cohort study. Lancet Neurol 2006;5:406-412.
33. Frank KA, Xu R. Causal inference for social network analysis. In: Light R, Moody J, editors. The Oxford handbook of social networks. New York: Oxford University Press, 2020, p.288-308.
34. Kim K, Kim S, Lee D, Park CY. Impacts of social distancing policy and vaccination during the COVID-19 pandemic in the Republic of Korea (No. 658). Manila: ADB Economics Working Paper Series; 2022.
35. KEIS. About KLoSA [Internet]. Available at: https://survey.keis.or.kr/eng/klosa/klosa01.jsp. Accessed January 8, 2023.
36. Zhang R, Shen L, Miles T, Shen Y, Cordero J, Qi Y, et al. Association of low to moderate alcohol drinking with cognitive functions from middle to older age among US adults. JAMA Netw Open 2020;3:e207922.
37. Tsai HJ, Chang FK. Associations of exercise, nutritional status, and smoking with cognitive decline among older adults in Taiwan: results of a longitudinal population-based study. Arch Gerontol Geriatr 2019;82:133-138.
38. Coe NB, von Gaudecker HM, Lindeboom M, Maurer J. The effect of retirement on cognitive functioning. Health Econ 2012;21:913-927.
39. Bonsang E, Adam S, Perelman S. Does retirement affect cognitive functioning? J Health Econ 2012;31:490-501.
40. Bond J, Dickinson HO, Matthews F, Jagger C, Brayne C; MRC CFAS. Self-rated health status as a predictor of death, functional and cognitive impairment: a longitudinal cohort study. Eur J Ageing 2006;3:193-206.
41. Bosma H, van Boxtel MP, Ponds RW, Jelicic M, Houx P, Metsemakers J, et al. Engaged lifestyle and cognitive function in middle and old-aged, non-demented persons: a reciprocal association? Z Gerontol Geriatr 2002;35:575-581.
42. Thomas PA. Gender, social engagement, and limitations in late life. Soc Sci Med 2011;73:1428-1435.
43. Green AF, Rebok G, Lyketsos CG. Influence of social network characteristics on cognition and functional status with aging. Int J Geriatr Psychiatry 2008;23:972-978.
44. Baumeister RF, Leary MR. The need to belong: desire for interpersonal attachments as a fundamental human motivation. Psychol Bull 1995;117:497-529.
45. Zubatsky M. Virtual groups to address the health of homebound adults during COVID-19: a biopsychosocial framework. J Nutr Health Aging 2021;25:281-283.
46. Kang J, Park J, Cho J. Inclusive aging in Korea: eradicating senior poverty. Int J Environ Res Public Health 2022;19:2121.
47. Statistics Korea. 2020 Senior Citizen Statistics [Internet]. Available at: https://kostat.go.kr/board.es?mid=a10301060500&bid=10820&act=view&list_no=385322. Accessed January 8, 2023.

Supplementary Table 1. Robustness: other mechanisms that affect cognitive function

	Alcohol	Smoking	Working status	Self-rated health	Marital status
	(1) Fixed effect [SE]	(2) Fixed effect [SE]	(3) Fixed effect [SE]	(4) Fixed effect [SE]	(5) Fixed effect [SE]
COVID19	-0.0068 [0.0089]	0.0029 [0.0026]	0.0176 [0.0482]	-0.0272 [0.0237]	-0.0016 [0.0058]
Observation	7,743 [2,882]	7,743 [2,882]	7,743 [2,882]	7,743 [2,882]	7,743 [2,882]

All statistics are based on a dataset created by the Korean Longitudinal Study of Aging for 2016–2020. SE, standard error; COVID-19, coronavirus disease-2019