

# BMJ Open Synergistic effect of interaction between perceived health and social activity on depressive symptoms in the middle-aged and elderly: a population-based longitudinal study

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## ABSTRACT

**Objective:** To examine the synergistic effect of interaction between perceived health and social activity on depressive symptoms.

**Methods:** We investigated whether the interaction between perceived health and social activity has a synergistic effect on depressive symptoms in the middle-aged and elderly using data from 6590 respondents aged 45 and older in the Korean Longitudinal Study on Aging (KLoSA), 2006–2012. A generalised linear mixed-effects model was used to investigate the association in a longitudinal data form. Depressive symptoms were measured using the Center for Epidemiological Studies Depression 10 Scale (CES-D10). Perceived health and level of social activity were categorical variables with three values. Participation in six social activities was assessed.

**Results:** Interactions between perceived health status and social activity were statistically significant for almost all social activity/perceived health combinations. Addition of the interaction term significantly decreased CES-D10 scores, confirming the synergistic effect of the interaction between perceived health status and social activity ('normal×moderate',  $\beta=-0.1826$ ; 'poor×moderate',  $\beta=-0.5739$ ; 'poor×active',  $\beta=-0.8935$ ). In addition, we performed stratified analyses by region: urban or rural. In urban respondents, the additional effect of the interaction term decreased CES-D10 scores and all social activity/perceived health combinations were statistically significant ('normal×moderate',  $\beta=-0.2578$ ; 'normal×active',  $\beta=-0.3945$ ; 'poor×moderate',  $\beta=-0.5739$ ; 'poor×active',  $\beta=-0.8935$ ). In rural respondents, only one social activity/perceived health combination was statistically significant, and the additional effect of the interaction term showed no consistent trend on CES-D10 scores.

**Conclusions:** The interaction between perceived health and social activity has a synergistic effect on depressive symptoms; the additional effect of the interaction term significantly decreased CES-D10 scores in our models.

## Strengths and limitations of this study

- To the best of our knowledge, it is the first to demonstrate the effect of an interaction between perceived health and social activity on depressive symptoms.
- It analysed data from a nationally representative sample.
- It had a large sample size.
- Social activity is just one way to measure social capital. Social networks, social support and social relationships were not considered in this study.
- The frequency of social activity was not considered.

## INTRODUCTION

We are living in an aging society. In Organization for Economic Cooperation and Development (OECD) countries, the proportion of the population aged 65 years and older has increased from less than 9% in 1960 to 15% in 2010 and is expected to nearly double in the next four decades, reaching 27% in 2050. In Korea, the elderly comprised 11% of the population in 2010 and are expected to exceed 37% in 2050.<sup>1</sup> In an aging society, the health and welfare of the elderly become major concerns.

Depression in later life has a substantial impact on affected individuals and their families.<sup>2</sup> Depression is treatable, but individuals often have a hard time recognising it and obtaining proper treatment.<sup>3</sup> Many studies have attempted to identify risk factors for depression. One prognostic indicator is self-rated perceived health. Those who report poor perceived health have greater odds of developing depression than those who report good perceived health.<sup>4</sup> In Korea, the percentage of adults who report good perceived health is 36.8%,

second to last among OECD countries.<sup>1</sup> The need for intervention is clear.

Social activity is inversely associated with depression.<sup>5</sup> For example, one study reported that a higher level of social activity is inversely associated with depressive symptoms in later life and positively associated with symptom improvement.<sup>6</sup> In addition, social isolation and lack of a social network are important risk factors for depression.<sup>7,8</sup> Thus, previous studies have shown that perceived health is positively associated with depression, and social activity is inversely associated with depression. However, whether social activity and perceived health status work together to moderate depressive symptoms is poorly understood.

We hypothesised that, when a statistical interaction between perceived health and social activity is present, a higher level of social activity will be more strongly associated with a decrease in depressive symptoms in those who reported poor perceived health. Thus, the purpose of this study was to examine whether social activity level has a synergistic effect on the relationship between perceived health and depression. A previous study found that factors associated with depression differed between urban and rural areas.<sup>9</sup> Therefore, we also performed an analysis stratified by location.

## METHODS

This study used data from the Korean Longitudinal Study on Aging (KLoSA). KLoSA is a national, representative, longitudinal study that follows-up participants every 2 years. The Korea Labor Institute conducts KLoSA, which is funded by the Korean Ministry of Labor, to investigate the aging process in Koreans and to use its findings in academic research and policy-making. Household members aged 45 and older were recruited using multistage probability sampling methods. As the KLoSA data are secondary data that do not contain private information and are available in the public domain, our study did not need to address ethical concerns. We drew on four waves of data collection, conducted between 2006 and 2012. In the 2006 baseline survey, trained interviewers interviewed 10 254 individuals from 6171 households (1.7 individuals per household) using a computer-assisted personal interviewing method. The second survey, in 2008, followed-up 8688 subjects, representing 86.6% of the original panel, with the exception of 187 decedents. The third survey, in 2010, followed-up 7920 subjects, representing 81.7% of the second wave, with the exception of 309 decedents. Finally, the fourth survey, in 2012, followed-up 7486 subjects, representing 80.1% of the third survey, with the exception of 327 decedents. We excluded newly added participants and decedents, as well as 896 participants with missing sociodemographic data. We used the first to fourth wave in KLoSA, which is four waves in 2006–2012, so there are four repeated measures for each individual. In total, we analysed data from 6590 participants aged 45 and older.

## Outcome measure: depressive symptoms

Depressive symptoms were assessed using the Korean version of the Center for Epidemiological Studies Depression 10 Scale (CES-D10). This self-report scale was designed to measure depressive symptoms in the general population. The items assess the presence of the following features over the previous month: feelings of depression, pessimism, irritability, tearfulness, fatigue, sleep problems, loss of interest, loss of appetite, reduced concentration, and loss of enjoyment. KLoSA's CES-D10 used a yes or no response format. Ten items were added together, resulting in a composite score ranging from 0 to 10 which was used as a continuous variable. On this scale, zero represents perfect mental health and 10 represents severe depression. The Boston version of the CES-D10 reported  $\alpha$  coefficients of 0.80 for older adults<sup>10</sup> and 0.92 for middle-aged individuals.<sup>11</sup>

## Independent variables

In this study, the primary independent variable was the interaction term between social activity and perceived health status. Interaction terms present synergistic effects of perceived health and social activity on depressive symptoms.

$$\begin{aligned} \text{CES-D10} = & (\text{Perceived health}) \times \beta_1 + (\text{Social activity}) \times \beta_2 \\ & + (\text{Perceived health} \times \text{Social activity}) \times \beta_3 \\ & + \text{covariates} \end{aligned}$$

In KLoSA, the social activity variable comprised six activities: 'religious organisations', 'friendship organisations', 'leisure/culture/sports clubs', 'school/family reunions', 'voluntary work' and 'political organisations'. Respondents who did not participate in any of these social activities were grouped in the 'none' category, respondents who participated in one or two social activities were grouped in the 'moderate' category, and respondents who participated in three or more activities were grouped in the 'active' category. Perceived health status was measured using a five-point scale: 'very good', 'good', 'normal', 'poor' and 'very poor'. Before analysis, these values were converted into three categories: 'good', 'normal' and 'poor'.

Covariates considered in this study were sex, age, household income, marital status, educational level, region (urban, rural), employment status, smoking status and alcohol use.

We also stratified analyses by region (urban, rural).

## Statistical analysis

Analysis of variance was used to analyse statistical differences with regard to CES-D10 scores. A generalised linear mixed-effects model was used to evaluate factors influencing depressive symptoms among middle-aged and elderly participants from 2006 to 2012 and, in particular, to analyse the associations between social activity, perceived health and depressive symptoms while

**Table 1** General sample characteristics at baseline (2006)

Characteristic	Number (N=6590)	Percentage
Perceived health status		
Good	2597	39.4
Normal	2128	32.3
Poor	1865	28.3
Number of social activities		
None	1667	25.3
Moderate	4409	66.9
Active	514	7.8
Sex		
Male	2859	43.4
Female	3731	56.6
Age (years)		
45–54	2188	33.2
55–64	2016	30.6
65–74	1736	26.3
75–84	596	9.0
>85	54	0.8
Education		
College graduate	630	9.6
High school graduate	1799	27.3
<High school	4161	63.1
Income		
Q4 (high)	1638	24.9
Q3	1537	23.3
Q2	1729	26.2
Q1 (low)	1686	25.6
Marital status		
Married	5419	82.2
Divorced, widowed, unmarried	1171	17.8
Type of household		
With family	6070	92.1
Alone	520	7.9
Chronic disease		
No	3592	54.5
Yes	2998	45.5
Job status		
Yes	2747	41.7
No	3843	58.3
Smoking status		
Current smoker	1254	19.0
Ex-smoker	634	9.6
Non-smoker	4702	71.4
Alcohol use		
Current	2587	39.3
Past	395	6.0
Never	3608	54.8
Region		
Urban	4846	73.5
Rural	1744	26.5

accounting for the longitudinal nature of the data, which required the incorporation of a correlated structure among observations. We used an ‘unstructured’ covariance structure, so that we could consider all covariance within subjects. All statistical analyses were carried out using SAS V.9.2.

## RESULTS

The characteristics of the study participants at baseline (2006) are shown in table 1. Of the 6590 participants, 1865 people reported poor, 2128 people reported normal, and 2597 people reported good perceived health. In addition, 1667 people did not participate in any social activity at all, 4409 people were moderately socially active, and 514 people were active.

Table 2 presents mean CES-D10 scores stratified by social activity, perceived health and other sociodemographic characteristics for each survey year. In terms of health, people with poor perceived health showed the highest CES-D10 scores (4.52 in 2006, 5.38 in 2008, 5.23 in 2010, and 5.21 in 2012), and people with good perceived health showed the lowest scores (1.80 in 2006, 2.36 in 2008, 2.57 in 2010, and 2.61 in 2012). In terms of social activity, active people had the lowest scores (1.67 in 2006, 1.87 in 2008, 2.45 in 2010, and 2.46 in 2012), and individuals who did not participate in any social activities had the highest (3.69 in 2006, 4.67 in 2008, 4.68 in 2010, and 4.71 in 2012). In addition, men had lower scores than women, and scores tended to increase with age. Finally, CES-D10 scores decreased as education level and household income increased.

Table 3 presents the generalised linear mixed-effects model results of waves one to four of KLoSA, which assessed the associations between social activity, perceived health and depression among the middle-aged and elderly. When all covariates were included in the model, CES-D10 scores differed significantly between individuals at each level of perceived health. Individuals with poor perceived health were more likely to have higher CES-D10 scores ( $\beta=2.1397$ ) than individuals with good perceived health. In addition, individuals with normal perceived health were more likely to have higher scores than individuals with good perceived health ( $\beta=0.6258$ ). Respondents who were socially ‘active’ were more likely to have lower scores than those with no social activity participation ( $\beta=-0.3756$ ). ‘Moderate’ respondents were also more likely to have lower scores than those with no social activity participation ( $\beta=-0.0711$ ,  $p>0.05$ ), but this difference was not statistically significant.

The interaction between perceived health status and social activity was statistically significant in all health/social activity combinations except ‘normal perceived health×active social activity’ ( $\beta=-0.281$ ,  $p>0.05$ ). Furthermore, addition of the interaction term significantly decreased CES-D10 scores, confirming the synergistic effect of the interaction between perceived health status and social activity. In individuals with poor perceived health, addition of the interaction term with social activity decreased CES-D10 score more (‘normal×less active’,  $\beta=-0.1826$ ; ‘poor×moderate’,  $\beta=-0.5739$ ; and ‘poor×active’,  $\beta=-0.8935$ ).

Table 4 presents an analysis of waves one to four of KLoSA stratified by region: urban or rural. In urban respondents, addition of the interaction term significantly decreased CES-D10 scores for all health/social

**Table 2** Mean CES-D10 depression scores of participants

Characteristic	2006			2008			2010			2012		
	Mean	SD	p Value									
Perceived health status												
Good	1.80	1.76	<0.0001	2.36	2.36	<0.0001	2.57	2.50	<0.0001	2.61	2.45	<0.0001
Normal	2.65	2.26		3.53	2.74		3.40	2.82		3.16	2.72	
Poor	4.52	2.93		5.38	2.88		5.23	3.01		5.21	3.06	
Social activity												
None	3.69	2.94	<0.0001	4.67	3.02	<0.0001	4.68	3.05	<0.0001	4.71	3.17	<0.0001
Moderate	2.66	2.38		3.43	2.81		3.34	2.87		3.27	2.79	
Active	1.67	1.78		1.87	2.23		2.45	2.65		2.46	2.58	
Sex												
Male	2.44	2.31	0.0114	3.10	2.77	0.0091	3.27	2.88	0.5417	3.30	2.88	0.9096
Female	3.16	2.70		4.00	2.94		3.94	3.01		3.83	2.99	
Age (years)												
45–54	2.30	2.22	<0.0001	2.80	2.57	0.0216	2.72	2.65	0.2602	2.68	2.59	<0.0001
55–64	2.58	2.45		3.22	2.78		3.11	2.75		2.92	2.70	
65–74	3.46	2.75		4.12	2.96		3.97	3.01		3.69	2.95	
75–84	3.86	2.80		4.86	2.99		4.66	3.06		4.78	2.99	
>85	3.80	2.82		5.05	2.92		4.65	3.15		5.14	3.09	
Education												
College graduate	1.88	1.88	0.0163	2.46	2.39	0.0114	2.42	2.48	<0.0001	2.79	2.65	0.6606
High school graduate	2.12	2.07		2.82	2.63		2.89	2.70		2.98	2.71	
<High school	3.31	2.72		4.13	2.96		4.16	3.03		4.00	3.02	
Income												
Q4 (high)	2.02	2.01	<0.0001	2.78	2.57	<0.0001	2.77	2.68	<0.0001	2.87	2.69	0.0374
Q3	2.56	2.34		3.09	2.74		3.20	2.82		3.12	2.80	
Q2	3.19	2.72		3.68	2.85		3.70	2.96		3.79	2.94	
Q1 (low)	3.55	2.78		4.82	3.00		4.84	2.99		4.56	3.06	
Marital status												
Married	2.56	2.38	<0.0001	3.32	2.81	<0.0001	3.36	2.89	0.0011	3.31	2.84	0.0008
Divorced, widowed, unmarried	4.15	2.94		4.80	2.99		4.70	3.03		4.63	3.09	
Type of household												
With family	2.72	2.48	0.7201	3.48	2.86	0.4607	3.50	2.94	0.0753	3.46	2.92	0.0872
Alone	4.32	2.95		4.87	2.98		4.97	2.93		4.74	3.00	
Chronic disease												
No	2.35	2.24	0.1213	2.94	2.68	0.0047	2.99	2.74	0.0758	2.90	2.65	0.0201
Yes	3.44	2.78		4.22	2.97		4.13	3.05		4.04	3.04	
Employment status												
Yes	2.28	2.23	<0.0001	2.91	2.62	<0.0001	2.99	2.74	<0.0001	2.75	2.59	<0.0001
No	3.25	2.70		4.18	3.00		4.16	3.04		4.16	3.04	
Smoking status												
Current smoker	2.75	2.60	0.0035	3.35	2.88	0.0236	3.44	2.90	0.1735	3.32	2.86	0.3200
Ex-smoker	2.63	2.36		3.28	2.75		3.43	2.94		3.51	2.98	
Non-smoker	2.90	2.57		3.73	2.93		3.74	2.99		3.69	2.96	
Alcohol use												
Current	2.53	2.39	0.0643	3.08	2.73	0.3448	3.14	2.76	0.0317	3.04	2.72	0.0013
Past	3.49	2.85		3.99	2.97		4.10	3.03		4.22	3.09	
Never	3.00	2.61		3.92	2.96		3.14	2.76		3.81	3.00	
Region												
Urban	2.72	2.53	0.0117	3.46	2.90	0.0002	3.54	2.96	0.0641	3.53	2.99	0.2350
Rural	3.21	2.61		4.03	2.86		3.96	2.99		3.80	2.84	

p Values for results by analysis of variance.

CES-D10, Center for Epidemiological Studies Depression 10 Scale.

activity combinations ('normal×moderate',  $\beta=-0.2578$ ; 'normal×active',  $\beta=-0.3945$ ; 'poor×moderate',  $\beta=-0.5739$ ; and 'poor×active',  $\beta=-0.8935$ ). In rural respondents, addition of the interaction term significantly decreased

CES-D10 scores for only one health/social activity combination ('poor×moderate',  $\beta=-0.4379$ ).

Table 5 presents a combined analysis model of association between perceived health, social activity and

**Table 3** Associations between perceived health, social activity, sociodemographic characteristics and CES-D10 depression score

	B	SE	p Value
Perceived health status			
Good	Ref	–	–
Normal	0.626	0.083	<0.0001
Poor	2.140	0.084	<0.0001
Social activity			
None	Ref	–	–
Moderate	–0.071	0.073	0.3298
Active	–0.377	0.115	0.0011
Perceived health status×social activity			
Good×none	Ref	–	–
Normal×moderate	–0.183	0.091	0.0447
Normal×active	–0.281	0.160	0.0797
Poor×moderate	–0.574	0.092	<0.0001
Poor×active	–0.895	0.228	<0.0001
Sex			
Male	Ref	–	–
Female	0.150	0.065	0.0220
Age (years)			
45–54	Ref	–	–
55–64	–0.098	0.049	0.0482
65–74	0.071	0.061	0.2456
75–84	0.288	0.077	0.0002
>85	0.275	0.129	0.0321
Education			
College graduate	Ref	–	–
High school graduate	0.121	0.082	0.1414
<High school	0.374	0.083	<0.0001
Income			
Q4 (high)	Ref	–	–
Q3	0.014	0.048	0.764
Q2	0.193	0.050	0.0001
Q1 (low)	0.295	0.056	<0.0001
Marital status			
Married	Ref	–	–
Divorced, widowed, unmarried	0.558	0.067	<0.0001
Type of household			
With family	Ref	–	–
Alone	0.168	0.083	0.0425
Chronic disease			
No	Ref	–	–
Yes	0.182	0.042	<0.0001
Employment status			
Yes	–0.345	0.041	<0.0001
No	Ref	–	–
Smoking status			
Current smoker	Ref	–	–
Ex-smoker	–0.149	0.067	0.0272
Non-smoker	–0.170	0.066	0.0104
Alcohol use			
Current	–0.067	0.053	0.2041
Past	0.251	0.071	0.0004
Never	Ref	–	–
Region			
Urban	–0.188	0.050	0.0002
Rural	Ref	–	–

p Values for results by analysis of generalised linear mixed-effects models.  
CES-D10, Center for Epidemiological Studies Depression 10 Scale.

CES-D10. If participants who have good perceived health are socially ‘active’, they have a 0.377 lower mean CES-D10 score than participants who have good perceived health and do not participate in social activity. Furthermore, if participants who have poor perceived health are socially ‘active’, they have a 1.272 lower mean CES-D10 score than participants who have poor perceived health and do not participate in social activity.

Figure 1 presents a graph for CES-D10 score of waves one to four of KLoSA by ‘perceived health×social activity’ combination. Each bar depicts the adjusted least squares mean for each ‘perceived health×social activity’ combination. The adjusted least squares mean of CES-D10 increases when perceived health is poorer, and decreases when the level of social activity is higher.

## DISCUSSION

An association between poor perceived health and depressive symptoms has been reported in many studies, as has an inverse association between social activity and depression.<sup>12–15</sup> The purpose of this study was to test the hypothesis that social activity can affect the relationship between perceived health and depression. As in previous studies, we found that poor perceived health was significantly associated with a higher CES-D10 score. Several studies have found that poorer perceived health is associated with higher levels of depression symptoms.<sup>4 16</sup> We also found that high levels of social activity were associated with significantly lower CES-D10 scores. Many studies have shown that higher levels of social engagement or social activity are associated with fewer depressive symptoms.<sup>6 17</sup> Other studies have similarly found that higher levels of social integration are associated with a lower risk of depression.<sup>18–21</sup>

Our major finding was that the interaction between perceived health and social activity significantly decreased CES-D10 scores for all perceived health/social activity combinations except one. In participants who reported poor perceived health, the interaction term with social activity was more strongly associated with CES-D10 score. Furthermore, the additional effect of the interaction term decreased CES-D10 scores more when perceived health was poor and social activity levels were high. Thus, we found that social activity has a synergistic effect on the relationship between perceived health and depressive symptoms. In figure 1, the synergistic effect of the interaction term is evident. Each bar in the figure depicts the adjusted least squares mean for each ‘perceived health×social activity’ combination. The graph shows that CES-D10 scores decrease as the level of social activity increases for each perceived health category, after adjustment for covariates. The most precipitous decrease associated with social activity was observed in participants with poor perceived health. In table 5, the total effect of interaction confirms a synergistic effect. Among those who have poor perceived health, people who are socially active have a lower CES-D10

**Table 4** Associations between perceived health, social activity, sociodemographic characteristics and CES-D10 depression score, stratified by region (urban, rural)

	Urban			Rural		
	B	SE	p Value	B	SE	p Value
Perceived health status						
Good	Ref	–	–	Ref	–	–
Normal	0.681	0.096	<0.0001	0.461	0.167	0.0057
Poor	2.272	0.098	<0.0001	1.826	0.165	<0.0001
Level of social activity						
None	Ref	–	–	Ref	–	–
Moderate	–0.073	0.083	0.3803	–0.724	0.285	0.0112
Active	–0.309	0.127	0.0148	–0.102	0.153	0.5047
Perceived health status×social activity						
Good×none	Ref	–	–	Ref	–	–
Normal×moderate	–0.258	0.105	0.0141	0.036	0.184	0.8438
Normal×active	–0.395	0.177	0.0256	0.205	0.393	0.6027
Poor×moderate	–0.629	0.107	<0.0001	–0.438	0.184	0.0171
Poor×active	–1.087	0.264	<0.0001	–0.273	0.467	0.5587
Sex						
Male	Ref	–	–	Ref	–	–
Female	0.201	0.075	0.0076	0.048	0.130	0.7104
Age (years)						
45–54	Ref	–	–	Ref	–	–
55–64	–0.148	0.055	0.007	0.062	0.111	0.5778
65–74	0.034	0.070	0.6303	0.189	0.128	0.1391
75–84	0.298	0.089	0.0009	0.296	0.151	0.0505
>85	0.369	0.152	0.0154	0.118	0.240	0.6240
Education						
College graduate	Ref	–	–	Ref	–	–
High school graduate	0.097	0.086	0.264	0.168	0.235	0.4747
<High school	0.346	0.089	<0.0001	0.403	0.223	0.0707
Income						
Q4 (high)	Ref	–	–	Ref	–	–
Q3	0.035	0.053	0.5035	–0.093	0.114	0.4145
Q2	0.265	0.057	<0.0001	0.008	0.112	0.9419
Q1 (low)	0.259	0.064	<0.0001	0.369	0.124	0.0029
Marital status						
Married	Ref	–	–	Ref	–	–
Divorced, widowed, unmarried	0.588	0.077	<0.0001	0.371	0.139	0.0077
Type of household						
With family	Ref	–	–	Ref	–	–
Alone	0.178	0.097	0.0665	0.246	0.160	0.1234
Chronic disease						
No	Ref	–	–	Ref	–	–
Yes	0.256	0.049	<0.0001	–0.015	0.083	0.8599
Employment status						
Yes	–0.242	0.049	<0.0001	–0.568	0.076	<0.0001
No	Ref	–	–	Ref	–	–
Smoking status						
Current smoker	Ref	–	–	Ref	–	–
Ex-smoker	–0.137	0.078	0.0785	–0.169	0.132	0.2014
Non-smoker	–0.174	0.076	0.0223	–0.096	0.135	0.4740
Alcohol use						
Current	–0.038	0.061	0.5376	–0.116	0.105	0.2680
Past	0.268	0.081	0.001	0.232	0.142	0.1039
Never	Ref	–	–	Ref	–	–

p Values for results by analysis of generalised linear mixed-effects models. CES-D10, Center for Epidemiological Studies Depression 10 Scale.

**Table 5** Combined table of association between perceived health, social activity and CES-D10

	B	SE	p Value
Perceived health status×social activity			
Good×none	Ref	–	–
Good×moderate	–0.071	0.073	0.3298
Good×active	–0.377	0.115	0.0011
Normal×none	0.626	0.083	<0.0001
Normal×moderate	0.372	0.073	<0.0001
Normal×active	–0.032	0.128	0.8043
Poor×none	2.140	0.084	<0.0001
Poor×moderate	1.495	0.079	<0.0001
Poor×active	0.868	0.206	<0.0001

All covariates in table 3 are adjusted.  
CES-D10, Center for Epidemiological Studies Depression 10 Scale.

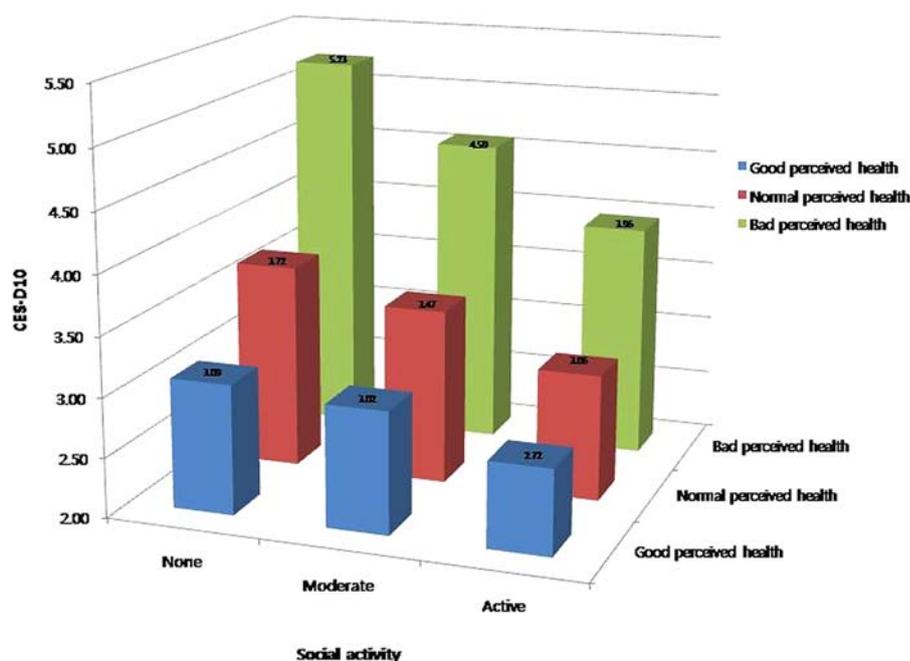
score than those who are not socially active. Therefore, the effect of social activity on the relationship between perceived health and CES-D10 score is increased in participants with poor perceived health.

In a subgroup analysis, we investigated the synergistic effect of social activity on the relationship between perceived health and CES-D10 by residential region: urban or rural. The synergistic effect of social activity appeared to be stronger in urban areas. As can be seen in table 4, the interaction term between perceived health and social activity was statistically significant for all perceived health/social activity combinations in urban residents, and addition of the interaction term decreased CES-D10 scores more than in the overall sample (table 3). By contrast, in rural residents, the interaction term between perceived health and social activity was only statistically significant for one perceived health/social activity combination. In addition, there were no consistent trends

observed with regard to perceived health status, and most categories were not statistically significant. We assume that this may be due to different levels of intimacy in urban and rural settings. Beggs *et al*<sup>22</sup> suggested that personal networks in rural settings have greater intensity and role multiplexity. People in rural areas have a more intensive personal network, which may explain why they are less affected by social activity than urban participants. However, further study is required on the different effects of different kinds of social activity in urban and rural settings.

Previous studies have found inverse associations between social activity and depression and positive associations between perceived health and depression. In this study, we found that the interaction between these two factors had a synergistic effect on depressive symptoms. For example, in participants who reported poor health, the association between social activity and depressive symptoms was stronger than in those who reported good health. This synergistic effect appears to be stronger in urban areas. Thus, the effect of the interaction between social activity and perceived health should be considered when establishing health policies. Self-rated perceived health is known to be a prognostic indicator of depression. Our study results suggest that focusing recommendations for social activity on the people who have poor perceived health is effective. It can greatly improve their depressive symptoms and prevent their mental health from becoming worse; this intervention can therefore prevent progression to clinical depression.

This study has a number of strengths. To the best of our knowledge, it is the first to demonstrate the effect of an interaction between perceived health and social activity on depressive symptoms. Second, it analysed data

**Figure 1** Adjusted least squares means for Center for Epidemiological Studies Depression 10 Scale (CES-D10) scores according to social activity level and perceived health status.

from a nationally representative sample. Finally, it had a large sample size. The study also has some limitations. First, social activity is just one way to measure social capital. Social networks, social support and social relationships were not considered in this study. Also, the frequency of social activity was not considered.

In conclusion, we found that the interaction between perceived health and social activity had a synergistic effect on depressive symptoms. Addition of this interaction term to our models resulted in a significant decrease in CES-D10 scores. Health policy makers should consider these associations when establishing health policies to address depression in later life among individuals with poor self-rated health.

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