Prospective associations of social isolation and loneliness with poor sleep quality in older adults

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Abstract

Purpose There is evidence for negative associations between social isolation and loneliness and sleep quality in older adults. However, it is unclear to what extent these two factors independently affect sleep quality. This study examined the simultaneous associations of social isolation and loneliness with sleep quality in a longitudinal study of older adults.

Methods Data were analyzed from the Social Environment and Biomarkers of Aging Study (SEBAS) in Taiwan collected in 2000 and 2006, involving a cohort of 639 participants (mean age=66.14, SD=7.26). Poisson regression models were conducted to examine the association of social isolation and/or loneliness with sleep quality at follow-up after adjusting for multiple confounding variables.

Results Univariate analysis showed that sleep quality was inversely associated with both social isolation and loneliness. After demographic, health, cognitive factors and depressive symptoms were controlled in multivariable analysis, social isolation at the baseline still predicted poor sleep quality 6 years later (incident rate ratio, IRR = 1.14; 95 % CI, 1.04–1.24; $p<0.01$), while the association between loneliness and sleep quality was no longer significant (IRR, 1.08; 95 % CI, 0.94–1.23; $p=0.27$). The results were unchanged when participants who had poor sleep quality at the baseline were excluded from the analysis.

Conclusions These findings confirm an adverse effect of social isolation on the sleep quality of older adults, but indicate that this effect is independent of loneliness. Social isolation and loneliness seem to have distinct pathways in affecting the sleep quality of older adults.

Keywords sleep quality, social isolation, loneliness, older adults

Introduction

Poor sleep quality is one of the most common complaints in older adults. An estimated 50% people aged 55 years and older experience some form of sleep problem with a frequency and severity greater than in younger age groups [1; 2]. The health and functional consequences of poor sleep quality in older adults include elevated levels of fatigue, reduced quality of life, increased risk for cardiovascular disease and psychiatric disorders [3-5]. There are many reasons for geriatric sleep disorders. Although much sleep research has focused on intrinsic or age-related factors, evidence exists to suggest the important role of social factors in shaping older adult's sleep.

Both structural aspects of social relationships such as social isolation and perceived isolation or loneliness have been related to sleep problems. Social isolation is a quantitative objective aspect of social relationships incorporating aspects such as network size, network diversity, and frequency of contact. Several previous studies have focused on associations of particular aspects of social isolation with sleep quality in older adults. For example, a series of studies of the National Social Life, Health and Aging Project (NSHAP) found that both negative marital relationships and low levels of social participation were associated with poorer sleep outcomes [6; 7]. A large sample study with Chinese older adults showed that compared with those who were living alone, living with a spouse or family member increased the odds of having good sleep quality by 11% [8].

Loneliness is typically defined as a qualitative, subjective evaluation of individuals' expectations of and satisfaction with actual social relationships [9]. Researches relating

loneliness with sleep quality have produced mixed results. Two longitudinal studies found that loneliness predicts decrements in subjective sleep quality in older people [10; 11], while a third study using more objective sleep measures showed that loneliness impacts upon the soundness or continuity of sleep, rather than on sleep duration and subjective sleep quality [12].

Evidence from these studies indicates that social isolation and loneliness both have a negative impact on sleep quality in older adults. However, most research has investigated either social isolation or loneliness. Although the social isolation and loneliness are typically correlated, there is some evidence for distinct effects of the two constructs on older adults' health, such as cognitive functions, dementia onset, and all-cause mortality [13-15]. Therefore, the implications for public health and intervention may be different for the two constructs, involving the targeting of social contact or the fostering of close emotional relationships. However, there is still no study investigating the simultaneous associations of social isolation and loneliness with sleep quality in older adults. It is therefore unclear to what extent social isolation and loneliness independently contribute to sleep quality, especially when other known risk factors are taken into account. Moreover, it has been argued that isolation and loneliness may interact in increasing risk for some adverse health outcomes[14]. Motivated by these concerns, this study aimed to explore the impact of social isolation and loneliness, individually as well as simultaneously, on sleep quality over a 6-year follow-up period using data from a representative sample of older adults in Taiwan.

Methods

Participants

This longitudinal analysis used data from the Social Environment and Biomarkers of Aging Study (SEBAS), which is an extension of the Taiwan Longitudinal Study on Aging (TLSA). The TLSA began in 1989 with a nationally representative sample of adults aged 60 and older. Younger refresher cohorts (age 50-66) were added in 1996. Participants of the SEBAS were randomly selected from the 1999 TLSA, which included participants from both the 1989 and 1996 TLSA (n=4440). The SEBAS included a comprehensive measure of socio-demographic variables, health status, health-related behaviors, and biological markers. Information on the research design and data collection of the SEBAS has been detailed elsewhere [16; 17].

The first wave of the SEBAS was conducted in 2000 with 1497 participants being interviewed and 1023 of them participating in the hospital-based health examination. A total of 757 participants were interviewed in the second wave of the SEBAS conducting in 2006 (89.5% response rate among survivors), and 639 of them (54 to 80-year age range) completed the health examinations assessment and left for the final analysis [16]. Study protocols and procedures were approved by the Institutional review board at Antai Medical Care Cooperation Antai Tian-Sheng Memorial Hospital in Taiwan.

Measures

Sleep quality

In the 2006 SEBAS, sleep quality was assessed by the Pittsburgh Sleep Quality Index

(PSQI), which is one of the most widely used self-report questionnaires for insomnia symptoms [18; 19]. PSQI measures both the quality and quantity of sleep over the previous month [20]. It assesses 7 sleep components including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of medication and daytime dysfunction. Each component weighted equally from 0-3. These 7 component scores are summed to obtain a global score ranging from 0-21, with higher scores indicating worse sleep quality. The clinical and psychometric properties of the Chinese version of PSQI have been formally evaluated by previous research with Taiwanese people [21; 22]. In the 2006 SEBAS, only the first 5 sleep domains of PSQI were used to yield a global PSQI score between 0-15[23].

The baseline sleep quality in the 2000 SEBA was defined by one single item taken from the Center for Epidemiologic Studies of Depression Scale (CES-D). Participants were asked: "In the past week, have you experienced sleep poorly (unable to sleep)?" Participants who answered 'never' or 'rarely (1 day)' were categorized as 'normal'. Those who with the answer of 'sometimes (2-3 days)' or 'often (4 or more days)' were grouped into 'poor'.

Social isolation and loneliness

Compared with measurements of single aspects of social integration, multidimensional measures of social isolation may be more relevant to health [24]. We therefore used an index comprised of different aspects of the social network. Four items were combined to create an index of social isolation, which was adapted from previous research [15; 25; 26]. One point was assigned if participants were not married/separated/divorced/widowed, living alone,

living in the rural township rather than urban township, small or big city, not participating in any social groups (e.g. religious groups, political groups, social service groups, professional groups, neighbourhood clubs, elderly clubs, or lineage organizations). Scores ranged from 0 to 4, with higher scores indicating greater social isolation. It was categorized into two groups by the top quartile (≥2 for high level of social isolation and <2 for low level of social isolation)[15].

Loneliness was accessed using one single item from the CES-D. Participants were asked, "In the last week, have you experienced loneliness (felt isolated, with no companions)?" where the answer options were 'never', 'rarely', 'sometimes', and 'often'. All those participants who responded 'sometimes' or 'often' were classified as "lonely", those who responded 'never' or 'rarely' were classified as "not lonely"[27-29].

Socio-demographic variables

Socio-demographic variables included age, sex, and education (no schooling, 1-6 years, ≥7 years). Marital status and household size were not included as covariates since they were used to calculate the index of social isolation.

Health-related behaviors

Smoking and drinking status were assessed by asking the participants whether they had smoked or drunk alcohol in the past six months [30]. Participants also reported the frequency of exercise in an average week, which was categorized into two groups (low: <6/week, high: 6+/week).

Health status

Weight and height were measured during health examinations in 2000. Body mass index (BMI) was calculated as weight (kilograms) divided by height (meters) in square. Participants were divided into two categories (obese/non-obese) according to the national criteria of obesity in Taiwan (obese: BMI≥27)[31]. Previous research showed significant associations of sleep with cardiovascular- and metabolic-related diseases[32; 33], as well as lower respiratory diseases[34]. Therefore, self-reported chronic diseases including high blood pressure, diabetes, heart diseases, stroke, and chronic lower respiratory diseases were chosen for this study. Participants were further asked about any difficulty they experienced in basic activities (ADLs) and instrumental activities(IADLs) of daily living[35]. A combination of ADLs and IADLs has been recommended for the assessment of functional impairment to enhance range and sensitivity of measurement and has been used in previous studies [36; 37]. Therefore, this study used the combination scores of ADLs and IADLs (range 0 to 36) at baseline to define difficulties in the activity of daily life, with higher scores indicating a higher degree of difficulties.

Cognitive functioning was assessed using the Short Portable Mental Status Questionnaire (SPMSQ), which is a 10-item measure [38]. The number of incorrect responses was summed, with higher scores representing a poor cognitive function. The severity of depressive symptoms was measured by the Chinese version of the CES-D, a 10-item questionnaire with good reliability and validity [39-41]. The CES-D is a 4-point scale that ranges from 0 to 3, with higher total scores indicating a higher level of depressive symptoms. Since two items (felt lonely and slept poorly) were taken from the original scale to define

social isolation and sleep quality, the total scores were summed from the other 8 items for this study.

Statistical analysis

Descriptive analyses were performed for all variables at baseline. The χ^2-tests or independent sample t-tests were conducted to examine differences between participants who engaged or not in the follow-up study. The differences in PSQI score between levels of factors at baseline were examined using Mann-Whitney U test or Kruskal-Wallis tests due to the violation of normality. Spearman's correlations were calculated to determine the associations between PSQI score and continuous variables at baseline. Upon completion of univariate analyses, variables that showed a significant association with the outcome were selected for the multivariate analyses. It has been suggested that variables whose univariate test had a *p*-value <0.25 should be included in the multivariate model, since using a more traditional level (such as 0.05) often failed to identify variables known to be important [42]. In this study, only BMI, diabetes and lower respiratory diseases had *p*-values higher than 0.25 (p=0.541, 0.353, and 0.593, respectively). Therefore, all variables, except the above three, were considered candidates for the multivariate model. The multivariate model was carried out by Poisson regression since the PSQI scores were positively skewed. Incident rate ratios (IRRs) (e^B) were calculated due to the nonlinear distribution of the PSQI score. Four models were fitted for the outcome. A fully adjusted model (Model 1) was constructed first to examine the associations between social isolation and sleep quality at follow-up by controlling for demographic variables, health-related behaviors, and health status at baseline.

A similar model was fitted to test the independent association of loneliness on sleeping quality (Model 2). Model 3 was conducted by adding both social isolation and loneliness into the fully adjusted model. Evidence from previous study showed gender differences existed in social isolation and its' association with health [43; 44]. In order to test whether the association of social isolation with sleep quality differed in men and women, a term that accounts for the interaction between social isolation and sex was added to the Model 3. A sensitivity analysis was conducted by excluding the participants who had a poor sleep quality at the baseline. Since obesity is considered a major risk factor for the development of obstructive sleep apnea (OSA), which would result in poor sleep quality, another sensitivity analysis was conducted by excluding the participants who were moderately to severely obese (BMI≥30) in Model 3. All analyses were conducted using IBM SPSS 22.0 and a *p* value <0.05 was considered statistically significant in this study.

Results

The mean age of this study population was 66.14 years (SD=7.26) at baseline, 56.5 % of the cohort was male, and 77.1% was married. The mean PSQI score at follow-up was 4.7 (SD=3.53). 25.8% and 8.6% participants were identified as socially isolated and lonely respectively according to our classification method. The point biserial correlation between social isolation (as a continuous variable) and loneliness (as a dichotomous variable) was 0.154 ($p<0.001$), which was relatively small.

Table 1 provides information about characteristics of participants at baseline. To examine potential bias of loss to follow-up, individuals participating in the follow-up study (n = 639) were compared on all variables at baseline data with those who did not engage (n = 384). The differences in PSQI score in 2006 grouped by baseline characteristics are also shown in Table 1. Participants who had poorer sleep quality at follow-up tended to be female, attain lower educational levels, not smoke, not drink alcohol, reported less exercise, had higher rates of blood pressure or stroke, and had poorer baseline sleep quality. There were no significant differences by BMI, diabetes, heart disease, chronic respiratory diseases, and cognitive impairment. The sleep quality was low-to-moderately associated with the age, combined ADL difficulties, depressive symptoms and isolation.

In the univariate analysis, the PSQI score of participants who had a high level of social isolation was significantly greater than the non-isolated group ($p<0.001$). This was the same for loneliness though to a lesser extent ($p<0.011$). The fully adjusted Poisson regression model (Model 1 in **Table 2**) indicated that social isolation level at baseline predicted sleep

quality at follow-up. Those participants who had a higher level of social isolation had a poorer sleep quality (IRR, 1.14; 95% CI, 1.04–1.24; $p<0.01$). Of the covariates at baseline, age, sex, education, smoking, exercise, high blood pressure, and stroke were significantly associated with sleep quality at follow-up. In contrast to social isolation, no significant association between loneliness and PQSI score was found in the fully adjusted model for loneliness (Model 2: IRR, 1.07; 95% CI, 0.94–1.23; $p=0.313$). When social isolation and loneliness were added in the fully adjusted model simultaneously (Model 3), the association between social isolation and sleep quality persisted (IRR, 1.13; 95% CI, 1.04–1.24; $p<0.01$), while the association between loneliness and sleep quality remained non-significant ($p=0.383$). When the social isolation by sex interaction term was added to Model 3, no significant interaction effects on sleep quality were found (IRR, 0.90; 95% CI, 0.76–1.06; $p=0.21$). **Fig. 1** showed the multivariable adjusted PQSI scores in 2006 stratified by isolation and levels of loneliness. Overall, it shows that participants with a high level of isolation had poorer sleep quality than those with a low level of isolation independent of their loneliness status. There was no significant difference in sleep quality between high and low loneliness groups. No significant interaction between isolation and loneliness was found ($p= 0.45$).

The sensitivity analysis that excluded participants with poor sleep quality at baseline (n=161) yielded a similar result to Model 3 (isolation: IRR, 1.16; 95% CI, 1.04–1.30; $p=0.01$; loneliness: IRR, 1.16; 95% CI, 0.94–1.44; $p=0.17$). The second sensitivity analysis that excluded participants whose BMI $\geq$ 30 at the baseline (n=41) also yielded a similar result to Model 3 (isolation: IRR, 1.12, 95% CI, 1.02–1.22, $p=0.02$; loneliness: IRR, 1.06; 95% CI,

0.92–1.22, p=0.49).

Discussion

The purpose of this study was to identify whether social isolation and loneliness are associated with poor sleep quality in older adults. In this longitudinal six-year follow-up cohort, higher PSQI score was found for both a high level of social isolation and loneliness at baseline. However, in multivariate analysis, when controlling for a comprehensive set of demographic and baseline health-related factors, participants who had a high level of social isolation remained 1.14 times more likely to have sleep problems 6 years later than participants who were not socially isolated. In contrast, subjective feeling of loneliness no longer showed an association with sleep. Moreover, the main association of social isolation with sleep was similar regardless of whether loneliness was included in the model.

Our results indicate that loneliness did not affect the independent association between social isolation and sleep quality, and this conclusion was unchanged when participants who had a poor sleep quality at baseline were excluded. These findings suggest that social isolation independently contributes to the poor sleep quality in later life, while loneliness does not appear to confound the effect of isolation. A discrepancy in the associations of social isolation and loneliness with sleep quality has been described. In fact, previous studies have found similar discrepancies for other health outcomes in older adults. For example, a cohort study in Netherlands found that feeling lonely rather than being alone was associated with an increased risk of clinical dementia in later life [14]. A study in England showed that social isolation was associated with higher mortality in older adults and that the effect was independent of the emotional experience of loneliness [15]. Another quite recent study from

Finland also showed that social isolation rather than loneliness predicted mortality 17 years later [45]. Our results once again highlight the need to study the health effects of social isolation and loneliness simultaneously.

Our finding of an association between social isolation and poorer sleep quality is consistent with previous studies, most of which suggest a negative impact of certain aspects of social isolation such as marital status, living alone, or social activities [8; 46]. We used a multidimensional measure of social isolation as opposed to assessing separate aspects of social connectedness. It has been proposed that this association can be understood from an evolutionary perspective [12; 47]. Throughout human evolution, a safe environment has been needed for protection from danger during sleep, and this need has typically been met by co-sleeping. More isolated individuals do not benefit from this process since sleeping alone does not provide the secure environment in which high-quality sleep is possible.

Loneliness was associated with poorer sleep quality in bivariate analysis but was not related to sleep quality after covariates had been taken into account. This may indicate that the deleterious effect of loneliness on sleep quality is mediated through other factors that were present at baseline. This may also explain the lack of consistency of our results with previous studies that suggested a negative role of loneliness on sleep quality[10; 11]. Neither of these studies included the multiple confounding variables we were able to assess, introducing the risk of confounding. Two other studies with younger participants found that loneliness has an impact upon the soundness or continuity of sleep, rather than on sleep duration, subjective sleep quality or daytime sleepiness[12; 48]. This seems to suggest that

loneliness might influence sleep in complex ways that cannot be robustly assessed with subjective measures of sleep quality.

The strengths of this analysis include the longitudinal design with representative population cohort in which it was possible to control for multiple health and demographic factors. There are also some methodological limitations. First, loneliness was assessed using only one direct question regarding the perception of loneliness in the last week. Despite wide use in the literature and strong correlations with several established multiple-item scales, this measure may be less reliable than a composite measure that taps multiple aspects of loneliness [14; 49; 50]. Second, sleep quality was self-reported, so there may be issues in interpretation, and there is some evidence that loneliness has differential associations with objective and subjective sleep quality[6; 12]. Moreover, sleep quality was only measured by the first 5 domains of PSQI, which may not be able to capture the whole construct of sleep experience. Future studies that incorporate both subjective and objective instruments (e.g., actigraphy, polysomnography) are desirable. Third, the sample attrition rate was high, which may be due to the high mortality in this aging population. Although there were no significant differences between individuals who were followed and not followed in the 2006 survey in terms of sex, exercise, smoking, drinking, BMI, some chronic conditions (i.e. heart disease and lower respiratory disease) and baseline sleep quality, those who did not engage in the second survey tended to be older, had lower education level, experience higher level of cognitive impairment, depressive symptoms, social isolation and loneliness (p for $\chi 2 < 0.05$). Since this subgroup of participants tends to be less healthy, selection bias may lead to an

underestimation of the association between social isolation, loneliness and sleep quality. Finally, this was an observational study, so causal conclusions cannot be drawn about the relationship between social factors and sleep quality.

Conclusion

In this 6-year longitudinal study, we simultaneously explored the associations of social isolation and loneliness on the sleep quality of older adults after controlling for multiple health and demographic factors. The findings confirm that social isolation is associated with poorer sleep quality in older adults and indicate that this effect is independent of the subjective feeling of loneliness. There are numerous programs designed to alleviate social isolation that are being evaluated in different centres[51]. It is possible therefore that older adults' sleep might benefit from social interventions. Programs that aim to foster social connections may have effects not only on wellbeing but also on older adults' sleep quality.

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Authors' Statement of Conflict of Interest and Adherence to Ethical Standards

The authors declare that they have no conflict of interest. All procedures, including the informed consent process, were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

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Table 1 Sample characteristics in 2000 and PSQI score in 2006 among different levels of factors at baseline

Variables	All n=1023	Non follow-up n=384	Follow-up n=639	*p* for $\chi 2$	2006 PSQI score	
					Mean ± SD	*p*
Demographic variables						
Age	1023	70.38±7.55	66.14±7.26	< 0.001[a]	ρ=0.098	0.015[b]
Sex				0.325		<0.001[c]
Female	433	40.4%	43.5%		5.37±3.47	
Male	590	59.6%	56.5%		4.23±3.49	
Marital status				< 0.001		0.02 [c]
Unmarried	298	38.8%	23.3%		5.36±3.61	
Married	725	61.2%	76.7%		4.53±3.49	
Education				0.003		<0.001[c]
No schooling	341	39.8%	29.4%		5.86±3.78	
1-6 years	413	36.7%	42.6%		4.41±3.39	
7+ years	269	23.4%	28.0%		4.07±3.23	
Health-related behaviors						
Current smoker				0.082		0.002[c]
No	781	73.4%	78.2%		4.92±3.53	
Yes	241	26.6%	21.8%		3.99±3.43	
Alcohol consumer				0.056		0.006[c]
No	785	80.2%	75.0%		4.92±3.53	
Yes	235	19.8%	25.0%		4.10±3.45	
Exercise				0.570		0.018[c]
Low	605	58.1%	59.9%		5.03±3.66	
High	417	41.9%	40.1%		4.27±3.28	
Health status						
BMI				0.129		0.541[c]
Obese	223	19.3%	23.3%		4.51±3.94	
Non-obese	800	80.7%	76.7%		4.76±4.43	
High blood pressure				0.002		0.008[c]

Yes	312	36.4%	27.1%		5.27±3.56	
No	709	63.6%	72.9%		4.51±3.50	
Diabetes				< 0.001		0.353[c]
Yes	149	20.1%	11.3%		5.18±3.63	
No	874	79.9%	88.7%		4.66±3.51	
Heart diseases				0.979		0.205[c]
Yes	141	13.9%	13.8%		5.06±3.57	
No	878	86.1%	86.2%		4.66±3.52	
Stroke				< 0.001		0.005[c]
Yes	34	6.0%	1.7%		8.55±4.61	
No	989	94.0%	98.3%		4.65±3.47	
Lower respiratory diseases				0.179		0.593[c]
Yes	86	90.1%	92.5%		4.86±3.44	
No	936	9.9%	7.5%		4.71±3.54	
Baseline sleep quality				0.766		<0.001[c]
Poor	274	27.8%	26.9%		6.66±3.44	
Normal	731	72.2%	73.1%		4.04±3.31	
ADLs/IADLs	1023	2.45±4.99	0.93±2.36	< 0.001 [a]	ρ=0.143	<0.001[b]
Cognitive impairment	1004	7.21±1.32	7.56±0.89	< 0.001 [a]	ρ=0.049	0.229 [b]
Depressive symptoms	1005	6.14±5.67	5.13±5.19	< 0.001 [a]	ρ=0.182	<0.001[b]
Social isolation	1023	1.37±0.93	1.03±0.86	< 0.001 [a]	ρ=0.133	0.001[b]
Social isolation (categorical)				< 0.001		<0.001[c]
High	323	41.1%	25.8%		5.68±3.76	
Low	700	58.9%	74.2%		4.40±3.39	
Loneliness				< 0.001		0.011[c]
Yes	114	16.1%	8.6%		6.30±3.96	
No	889	83.9%	91.4%		4.43±3.37	

a: Independent sample t-test; b: Spearman's correlation; c: Mann-Whitney U test or Kruskal-Wallis test

Table 2 Poisson regression models for standardized regression coefficients of social isolation and loneliness for predicting sleep quality (n = 639)

Variables	Model 1 Social isolation			Model 2 Loneliness			Model 3 Social isolation+loneliness		
	IRR	95% CI	*p*	IRR	95% CI	*p*	IRR	95% CI	*p*
Age	1.01	1.00-1.01	0.015	1.01	1.00-1.01	0.008	1.01	1.00-1.01	0.017
Sex									
Male	1			1			1		
Female	1.09	0.99-1.20	0.073	1.10	1.00-1.21	0.045	1.10	1.00-1.21	0.049
Education									
7+ years	1			1			1		
1-6 years	1.04	0.95-1.15	0.409	1.05	0.96-1.16	0.298	1.05	0.95-1.15	0.374
No schooling	1.21	1.08-1.36	0.001	1.24	1.10-1.38	<0.001	1.22	1.09-1.37	0.001
Current smoker									
Yes	1			1			1		
No	1.12	1.00-1.25	0.048	1.12	1.00-1.25	0.055	1.13	1.01-1.26	0.038
Alcohol consumer									
Yes	1			1			1		
No	1.06	0.96-1.17	0.273	1.05	0.95-1.17	0.307	1.06	0.96-1.17	0.269
Exercise									
High	1			1			1		
Low	1.12	1.03-1.22	0.005	1.13	1.05-1.23	0.002	1.12	1.03-1.21	0.006
High blood pressure									

No	1			1			1		
Yes	1.10	1.01-1.20	0.023	1.10	1.01-1.20	0.024	1.10	1.01-1.20	0.023
Heart diseases									
No	1			1			1		
Yes	0.98	0.88-1.10	0.750	0.99	0.89-1.10	0.823	0.98	0.88-1.10	0.982
Stroke									
No	1			1			1		
Yes	2.12	1.70-2.64	<0.001	2.12	1.70-2.64	<0.001	2.14	1.72-2.67	<0.001
Baseline sleep quality									
Normal	1			1			1		
Poor	1.54	1.41-1.67	<0.001	1.53	1.41-1.67	<0.001	1.53	1.41-1.67	<0.001
ADLs/IADLs	0.98	0.91-1.04	0.482	0.98	0.91-1.05	0.523	0.97	0.91-1.04	0.391
Cognitive impairment	1.12	0.80-1.56	0.495	1.06	0.76-1.48	0.734	1.11	0.79-1.55	0.549
Depressive symptoms	1.03	0.99-1.07	0.167	1.03	0.99-1.08	0.148	1.03	0.98-1.07	0.228
Social Isolation									
Low	1						1		
High	1.14	1.04-1.24	0.004				1.13	1.04-1.24	0.005
Loneliness									
No				1			1		
Yes				1.07	0.94-1.23	0.313	1.06	0.93-1.21	0.383

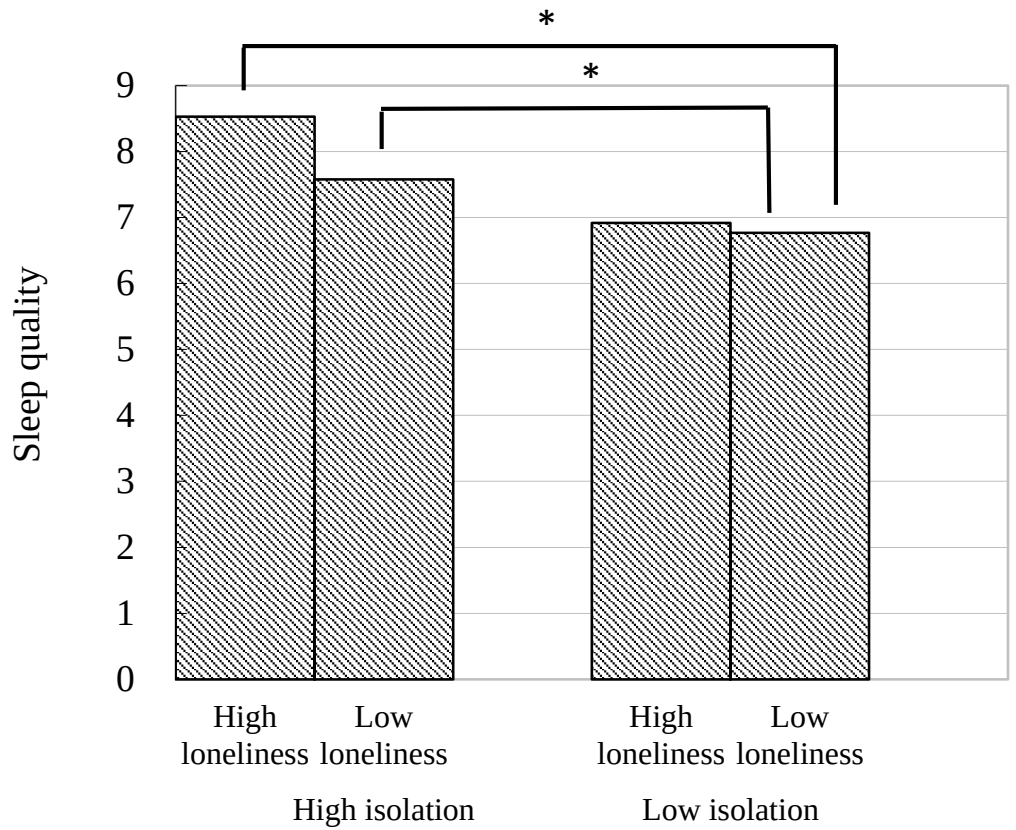

Fig. 1 Multivariable adjusted scores of sleep quality in 2006 stratified by isolation and levels of loneliness. The adjusted means of sleep quality (higher scores indicating worse sleep quality) was estimated using the Poisson regression after adjusting for all the covariates in Table 2. The pairwise comparisons with significant differences were shown. (* $p< 0.05$)