Metropolitan urban hotspots of chronic sleep deprivation: evidence from a community health survey in Gyeongbuk Province, South Korea

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Abstract

The geographic concentration of chronic sleep deprivation (CSD) remains largely unexplored. This paper examined the community-specific spatial pattern of the prevalence of CSD and the presence of clustered spatial hotspots among the Korean elderly population in Gyeongbuk Province, South Korea, revealing CSD hotspots and underscoring the importance of geography-focused prevention strategies. The study analysed cross-sectional data collected from 9847 elderly individuals aged 60 years and older who participated in a Korean Community Health Survey conducted in 2012. To assess the level of spatial dependence, an exploratory spatial data analysis was conducted using Global Moran's I statistic and the local indicator of spatial association. The results revealed marked geographic variations in CSD prevalence ranging from 33.4 to 73.4%, with higher values in the metropolitan urban areas and lower in the rural areas. Almost half of the community residents [both men (44.1%) and women (53.5%)] slept 6 h or less per 24 h. The average CSD prevalence (53.6% men and 65.1% women) in the hotspots was about 13.0% higher than that in other areas (42.6% for men and 51.1% for women). To our knowledge, this is the first study to generate a CSD hotspot map that includes data on sleep deprivation across metropolitan district levels. This study demonstrates that not only is sleep deprivation distributed differentially across communities but these differences may be explained by urbanisation.

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Key words: Chronic sleep deprivation; Elderly; Hotspots; Metropolitan urban; South Korea.

Ethical statement: participants willing to participate were required to sign informed consent forms approved by the Institutional Review Board of the KCDC. The survey procedures were carried out in accordance with the principles in the Declaration of Helsinki.

Funding: this work was supported by the Human Resources Program in Energy Technology of the Korea Institute of Energy Technology Evaluation and Planning (KETEP), granted financial resource from the Ministry of Trade, Industry & Energy, Republic of Korea (No. 20144010200670).

Acknowledgments: the 2012 Community Health Survey (CHS) in Gyeongbuk Province and Daegu Metropolitan City was supported by Korean Centers for Disease Control and Prevention. The authors would like to thank all respondents in the 2012 CHS and all members of the 2012 CHS team in Gyeongbuk Province and Daegu Metropolitan City.

Received for publication: 29 May 2015.
Revision received: 13 August 2015.
Accepted for publication: 28 August 2015.

Geospatial Health 2015; 10:382
doi:10.4081/gh.2015.382

Introduction

A growing body of evidence demonstrates a close relationship between chronic sleep deprivation (CSD) and adverse health behaviours (*e.g.*, physical inactivity and poor eating habits) increasing the risk of morbidity and mortality in elderly populations (Bin *et al*., 2012; Kurina *et al*., 2013). However, only a few studies have quantified the prevalence of CSD at the community level, which would simplify the complex, community-wide process in the real world. Geographical analysis may provide a better understanding of CSD prevalence and related social and health problems (Wissow *et al*., 2001). Epidemiologists have recognised that the geographical prevalence of CSD may not be randomly distributed. Although few such studies have examined CSD-related phenomena, many suggest the likely existence of spatial patterns of CSD risk (Stranges *et al*., 2008; Hense *et al*., 2011; Harrington *et al*., 2014). Among countries in the Organization for Economic Co-operation and Development (OECD), South Korea has the fastest-growing elderly population and lowest birth rate. As of 2012, 11.8% of Koreans were 65 years of age and older. This group is expected to account for 24.3% of the total population by 2030 and 37.4% by 2050 (Korean Statistical Information Service, 2012). In Korea, the number of elderly individuals experiencing CSD has increased along with the increasingly elderly population (Ryu *et al*., 2011). It is unclear whether empirical findings in Western countries can be generalised to include Korea; for example, Korean elderly people have, on average, earlier waking and later bed times than their Western counterparts. Spatial clustering techniques are particularly suited for visualising regional differences in CSD prevalence and to assess whether different local conditions can cause or worsen CSD within elderly individuals. Spatial clusters (measures of geographic concentration) can offer

community health researcher visual evidence to develop more effective community-based strategies. However, despite growing interest in this issue, very few studies have empirically explored spatial hotspots of CSD prevalence among elderly populations across communities. Spatial analysis of CSD prevalence may provide a better understanding of how local conditions contribute to CSD and facilitate CSD prevention strategies customised to local conditions. This paper investigated community-specific spatial hotspots of CSD prevalence among the elderly in Gyeongbuk Province, South Korea. The findings may be relevant for other countries with similar CSD spatial epidemiology contexts.

Materials and Methods

This study used publicly available data from the 2012 Korean Community Health Survey (KCHS) conducted across 253 local districts (Kim *et al*., 2012; Oh *et al*., 2013). The KCHS is a nationally representative, cross-sectional survey of the non-institutionalised civilian population carried out by the Korean Centers for Disease Control and Prevention (KCDC). A complex, stratified, multi-stage probability sampling design was applied in this survey to represent the national population of South Korea. KCHS has been conducted annually since 2008 by 253 community health centres and 36 community universities using 1500 trained interviewers to determine the patterns of disease prevalence and morbidity as well as to understand personal lifestyles and health behaviour of adults aged 19 years and older. The KCHS is conducted through face-to-face interviews in the participants' homes and each interview is verified within a week through a telephone survey. The KCHS was upgraded through the introduction of computer-assisted personal interviews in 2010. The KCHS has provided important insights into the annual health status of the populations of 253 local districts. The KCHS allocates sample numbers to each administrative region according to the population distribution of sex and age groups and uses a standardised questionnaire to directly compare differences in health issues between communities.

Sixty years is the standard age for retirement and pension eligibility in Korea. Although the elderly population is defined as those aged 65 years and older, we assumed that the sleeping environments of retired people 60 to 64 years of age would be similar to that of the elderly population. Therefore, while the elderly were the target population in our study, we also included individuals 60 to 64 years of age in our analysis. After excluding participants aged less than 60 and those residing outside of Gyeongbuk Province and Daegu Metropolitan City, a total of 11,580 participants were selected from 228,921 participants surveyed in 2012. The sleep duration was determined according to how many hours a participant reported sleeping per day on average (total sleep time), which was recorded as a continuous variable. In order to explore spatial hotspots based only on sleep deprivation, we excluded participants with normal sleep (7 or 8 hours) and excessive sleep (9 hours or more) as well as those who did not respond to questions regarding sleep duration. Additionally, to reflect local influences on CSD, those who had resided in a region for less than 10 years were also excluded. Thus, data from a total of 9847 participants aged 60 and over were analysed, and all analyses were performed separately by sex (4047 men and 5800 women).

Korea's administrative regions can be classified into three groups based on population: counties (less than 50,000), cities (more than 50,000) and metropolitan cities (more than 1,000,000). Gyeongbuk Province is the Korea's largest province with a single metropolitan city (the Daegu Metropolitan City, which is divided into 7 municipal districts and 1 county), 10 cities and 13 counties. We analysed data from this province, each is located in the southeastern region of the Korean Peninsula, with a total area of 19,025 km^2 (19.0% of total area of South Korea), and a total population of 2,696,446 as of 2013. Daegu covers 2813 km^2 and is densely populated (2.5 million people). The province has the country's second largest population of elderly residents, with approximately 17.0% of the residents aged 65 and over as of 2012 (Korean Statistical Information Service, 2012). The province is characterised by a pronounced socioeconomic variation, residential segregation based on rural and urban areas as well as differences between industrial and rural communities (Kim *et al*., 2003). The entire community areas in Gyeongbuk and Daegu were used as the unit of analysis to ensure geographic continuity and the analysis included a total of 30 communities. The community areas assessed were heterogeneous providing valuable information for assessment of regional differences in CSD among the elderly. In this regard, Gyeongbuk provides a valuable opportunity for in-depth analysis of sleep epidemiology as it serves as an important source of sleep data in an elderly population facilitating implementation of effective community-based initiatives for addressing sleep problems.

Both the CBD area and inner city itself are known for heavy concentration of wealth and high standards of living. Luxury apartment towers are an increasingly popular housing option in the CBDs and the inner city. These buildings have hi-tech amenities and built-in security and offer a variety of services, including fitness centres and convenient areas for shopping. South Korea is known for its high standard of education and intense competition for university entrance. The Suseong district, located in the inner city of Daegu, is considered the regional capital of education, one of the decisive factors that make Suseong District the most attractive destination in Gyeongbuk Province. The distinctive function of rural and metropolitan communities can have considerable influence on habitual sleep patterns and sleep-related lifestyles.

Spatial analyses of CSD prevalence were conducted in ArcGIS 10.1 (ESRI, Redlands, CA, USA). For visualisation of CSD prevalence, a chloropleth map was generated (Figure 1). Global Moran's I spatial autocorrelation statistics was used to determine clustering of CSD prevalence based on geographic proximity and attribute similarities. The Moran's I index was computed multiple times with increasing distance thresholds based on the square of the inverse distance (*i.e*. the Manhattan distance option) until the maximum z-score was obtained. CSD prevalence was clustered up to the distance threshold of 41,116 m at P=0.001. The local indicator of spatial association (LISA) was calculated to decompose global statistics into localised indices of spatial autocorrelation (Anselin, 1995). Local Moran's I coefficients were calculated for men and women based on the square of the inverse distance to obtain more significant results for measuring global spatial autocorrelation. Hotspots were analysed to identify spatial clusters of significant high or low-attribute values by determining whether high or low values (but not both) would cluster within a given area. Statistical analyses were performed using SAS Version 9.2 (SAS Institute, Inc. Cary, NC, USA).

Results

Table 1 shows the weighted CSD prevalence for 30 administrative areas by sex. Almost half of the community residents in Gyeongbuk slept 6 h or less per day. The prevalence varied from low to extremely high (lower than 33.4% or higher than 73.4%). Regardless of sex, dis-

trict areas in the Daegu metropolitan region showed higher CSD prevalence than cities and counties. Among men, the CSD prevalence in the districts varied from 44.7 to 55.3%, while cities and counties varied from 41.0 to 48.8% and 33.4 to 46.1%, respectively. The CSD prevalence was also higher among women in the districts (50.3 to 73.4%), though the prevalence was significantly higher compared to men (P=0.0094). While the CSD prevalence ranged from 45.1 to 64.3% in the cities (P=0.0022) and 43.0 to 61.2% in the counties (P=0.0002), the prevalence at the district level ranged from 50.3 to 73.4%. This finding suggests that more than half of the elderly population residing in the metropolitan cities of Daegu suffered from sleep deprivation. For both groups, the standard deviation (SD) ranged from 5.8 to 8.0% from the mean, while the minimum prevalence was similar for both groups (Table 2). However, the female participants showed 18.0% higher maximum prevalence values (73.4%) than the male participants (55.3%).

After dividing the CSD prevalence into quartiles, the 1st and 4th quartiles were compared. The 4th quartile was related to the metropolitan urban and industrial areas, whereas the 1st quartile was related to rural

Table 1. Prevalence of chronic sleep deprivation in different administrative divisions by sex.

Administrative division	Men		Women		P
	Number of participants	CSD prevalence° (%)	Number of participants	CSD prevalence° (%)	
Total	4047		5800		
District					0.0094
Nam	96	55.3	128	58.4	
Dalseo	55	46.1	70	50.3	
Dong	93	45.7	107	51.8	
Buk	65	54.2	84	62.7	
Seo	95	53.1	117	62.8	
Suseong	74	51.5	89	68.0	
Jung	99	44.7	159	73.4	
City					0.0022
Gyeongsan	69	47.2	96	47.9	
Gyeongju	115	47.9	170	56.8	
Gumi	163	44.1	226	56.4	
Gimcheon	126	45.9	183	57.7	
Mungyeong	175	48.8	218	61.3	
Sangju	165	41.1	231	45.1	
Andong	133	41.0	161	47.7	
Yeongju	108	46.1	167	52.6	
Yeongcheon	138	51.0	204	51.2	
Pohang	202	48.2	387	64.3	
County					0.0002
Yecheon	192	39.8	248	48.1	
Uljin	167	46.1	243	43.2	
Uiseong	180	36.0	270	50.8	
Cheongdo	160	36.7	248	48.8	
Cheongsong	174	40.6	247	50.0	
Chilgok	107	37.3	154	56.3	
Dalseong	79	45.4	101	61.2	
Goryeong	145	33.4	210	46.8	
Gunwee	219	34.3	316	43.0	
Bonghwa	180	42.1	222	44.4	
Seongju	150	36.5	264	39.1	
Yeongdeok	158	44.3	259	58.9	
Yeongyang	165	38.7	221	44.9	

CSD, chronic sleep deprivation. °Estimated using weighted samples.

Table 2. Descriptive statistics of chronic sleep deprivation prevalence by sex.

	CSD prevalence (%)	
	Men	Women
Mean±SD	44.1±5.8	53.5±8.1
Minimum/maximum quartiles	33.4/55.3	39.1/73.4
1st quartile	[33.45-40.01]	[39.10-47.75]
2nd quartile	[40.02-45.06]	[47.76-51.48]
3rd quartile	[45.07-47.69]	[51.49-58.81]
4th quartile	[47.70-55.32]*	[58.82-73.39]°

CSD, chronic sleep deprivation; SD, standard deviation. *Districts considered were Daegu Seo, Nam, Buk, Suseong; cities were: Pohang, Mungyeong, Yeongcheon, Gyeongju; °districts considered were: Daegu, Seo, Jung, Buk, Suseong; cities were: Pohang, Mungyeong, Yeongdeok; county: Dalseong. Values were estimated using weighted samples.

communities as shown in Table 2 and Figure 1. For both groups, the higher-risk areas in the 4th quartile were identified in urban and industrial areas in the southern region, including Daegu, Pohang City, and Mungyeong City. This indicates that elderly residents in the northern, central, and eastern regions were at a lower risk than those in the urbanised central, western, and southern regions. The high prevalence of CSD in the central region of Daegu corresponds to the most densely populated and built districts in the city.

The spatial correlations and corresponding P-values estimated by the Global Moran's I statistic were 0.64 (P=0.001) and 0.86 (P<0.001) for men and women, respectively (Table 3). This suggests non-randomness in the overall spatial pattern of CSD prevalence across the study area. In addition, z-scores for both data sets were high and positive (3.23 for men and 4.27 for women). Ultimately, there were clustered patterns in both datasets. Table 4 shows the local Moran's I statistics (decomposition of the global Moran's I statistic) and provides a list of communities within the CSD hotspots, the range of CSD prevalence for the hotspots and the non-clustered areas (cold spots), the significance for each z-score and the association between hotspot communities. For statistically significant z-scores, larger z-scores indicate more intense clustering of high values (hotspots), while smaller z-scores indicate more intense clustering of low values (cold spots). The hotspots consisted entirely of central business districts (CBD) and inner city districts of Daegu for both groups, while the cold spots consisted mainly of individual counties with rural populations (Figure 2). The average CSD prevalence (53.6% for men and 65.1% for women) in the hotspots was about 13% higher than that in the cold spots (42.6% for men and 51.1% for women (Table 4).

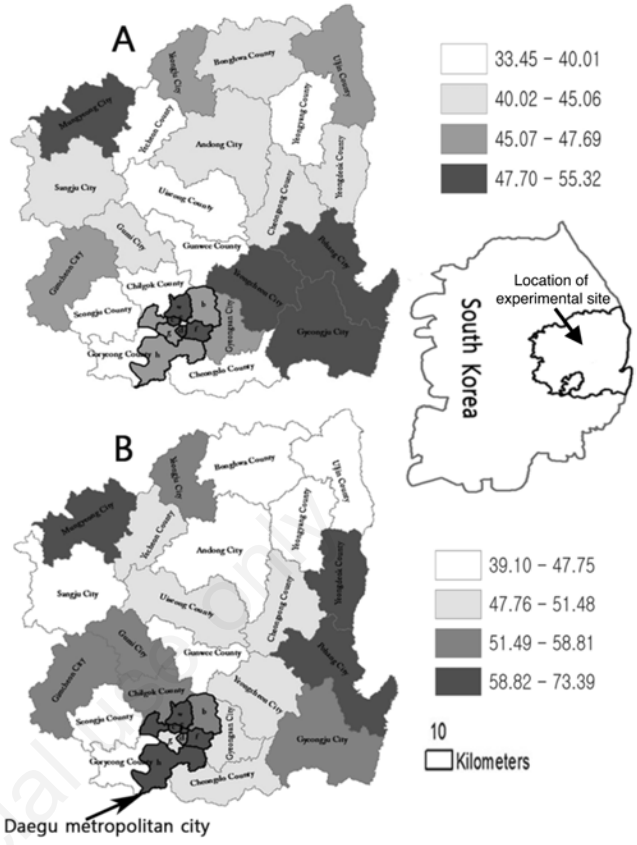

Figure 1. Quartile distribution map of chronic sleep deprivation prevalence: A) men; B) women. In Daegu Metropolitan City: a) Buk District; b) Dong District; c) Seo District; d) Nam District; e) Jung District; f) Suseong District; g) Dalseo District; h) Dalseong District.

Discussion

Overall, the results indicate that participants in metropolitan urban areas are the most likely to report CSD, whereas those in rural communities are the least likely to do so. Various studies (Krueger and Friedman, 2009; Grandner *et al*., 2012) have examined spatial variations in CSD, but mainly focused on the state level in the United States. There is limited empirical evidence of regional differences in CSD in the elderly population at the district level. However, state-wide averages can hide such differences; we therefore investigated a large number of small communities in Gyeongbuk. Our results are consistent with the findings of previous geographical studies showing that communities in large cities are likely to have increased risk of CSD (Hale

Table 3. Global Moran's index summary by sex.

	Men	Women
Moran's index	0.64	0.86
z-score	3.23	4.27
P	0.001	<0.001

Values were estimated using weighted samples.

Table 4. Characteristics of spatial hot and cold spots by sex.

Community	Men		Women	
	Hotspots	Cold spots	Hotspots	Cold spots
Type	Central business districts	Individual counties, rural populations	Central business districts	Individual counties, rural populations
Administrative division (districts)	Buk, Jung, Nam, Seo, Suseong	Remaining areas	Nam, Buk, Seo, Suseong, Jung	Remaining areas
CSD prevalence (%)				
Mean±SD	53.6±1.6	42.6±4.9	65.1±5.74	51.5±6.5
Min/max	51.6/55.4	33.4/51.0	58.5/73.4	39.0/64.3
z-score*				
Mean±SD	3.14±0.14	0.06±1.0	3.43±0.9	-0.14±0.78
Min/max	3.0/3.4	-2.4/2.1	1.9/4.8	-1.6/1.5

Hotspots, high positive z-score (clustered); cold spots, low negative z-score (dispersed); CSD, chronic sleep deprivation; SD, standard deviation. *Values were estimated using weighted samples.

and DP., 2006; Hill *et al*., 2009; Grandner *et al*., 2012). The results provide support for previous research by verifying sharp regional differences in CSD prevalence across Korean communities at the district level.

Many researchers have investigated sleep duration by considering small clinical samples (Bin *et al*., 2012; Kurina *et al*., 2013). By examining CSD prevalence in such a large sample as ours across many communities, huge differences in CSD prevalence among metropolitan districts and clear regional patterns could therefore be observed.

It is unclear why urban participants living in metropolitan cities have different outcomes, and the spatial dimension of CSD varies according to how a given society constructs the space that must be shared between various activities and sleep. The typical attributes of differences in CSD prevalence, including poverty, neighbourhood quality and ethnic background (Grady and McLafferty, 2007; Michael, 2009; Gu *et al*., 2010; Harrington *et al*., 2014) can be reinterpreted based on Korea's long cultural isolation and racial homogeneity. Korean values, attitudes and behaviour may not work in the same way in the West, at least not in the context of CSD. Korea is a homogeneous society with an absolute majority of Korean ethnicity (Shin, 2006; CIA, 2008). Ethnic differences in CSD could thus not be attributed to different cultures or lifestyle factors as reported in the West. However, Korea has experienced a rapid industrialisation since the 1970s that has resulted in many farmers having moved from rural to urban areas for more profitable jobs. High-rise building blocks of high-income families are typically concentrated in urban business districts in metropolitan cities and high-income residential areas generally surround the commercial centres in the cities (Ha, 2006). This is mainly due to the land costing so much more; shops and businesses counter this by creating tall buildings to provide more area in their shops or homes at a more affordable price. In this regard, poverty may not be the leading cause of CSD in the context of this paper (Smith, 1989). The Daegu city centre, like most metropolitan urban areas in Korea, is characterised by dense high-rise buildings and a heavy road network that causes excessive levels of noise as well as light exposure at night.

Many elderly individuals in metropolitan urban communities are likely to have faced high employment for many years, and a majority of them are likely to be homeowners in metropolitan communities. Elderly individuals still living in the same urban community through adulthood are likely to be exposed to lifestyles disruptive to sleep. For example, it is not unusual for some people to spend long hours each night studying to gain entry to the extremely competitive university and workplace system (Lee, 2003). Metropolitan adults have a tradition of long working hours with associated reduction in sleep duration. Elderly residents may face epidemiologically similar sleep environments through establishing interdependent relationships in hard-working communities in the inner city and by strengthening their sense of belonging to these communities. The results indicate that chronic exposure to disturbing environments during adulthood can be an important risk factor for elderly CSD. Although the cause of these relationships cannot be easily determined, the results raise the possibility that disruptive sleep patterns in adulthood may lead to the progressive deterioration of the physiological ability to restore normal sleep. It is well known that most elderly individuals experience a gradual decline in their cognitive function and diminished responses to environmental stress. Therefore, it may not be easy for elderly individuals to restore their sleep patterns after their retirement, since their sleep patterns may have been disrupted through adulthood. The results of our study are consistent with the findings of previous longitudinal studies on the continuity of CSD (Morgan and Clarke, 1997; Janson *et al*., 2001; Hublin *et al*., 2007). Previous studies have investigated the same group of participants over various development periods, reporting that fragmented and restricted sleep in elderly individuals tends to develop as a secondary symptom of adult sleep disturbance. These findings suggest that elderly individuals living in metropolitan urban communities are less likely to restore their natural sleep patterns after retirement because of prolonged exposure to disruptive sleeping environments since adulthood. However, this speculation requires additional studies.

This paper has some limitations. First, due to the cross-sectional study design, measurements for each participant were obtained at a single point in time thereby limiting the ability to identify trends of sleep deprivation over time. Second, this study relied on self-reported data on sleep duration. Subjectively measured perceived sleep duration may differ from objective measurements because of the effects of personal characteristics such as cognitive deficits; thus, the exclusive use of self-reported measures may introduce some bias. However, previous studies have found strong relationships between self-reported sleep duration and data from actigraphic monitoring (Hauri and Wisbey, 1992; Lockley *et al*., 1999). Although self-administered questionnaires are not as accurate as actigraphy or polysomnography, simple, fast, and short questionnaires are widely used in large epidemiological studies where objective examinations may not be practical. Individuals with

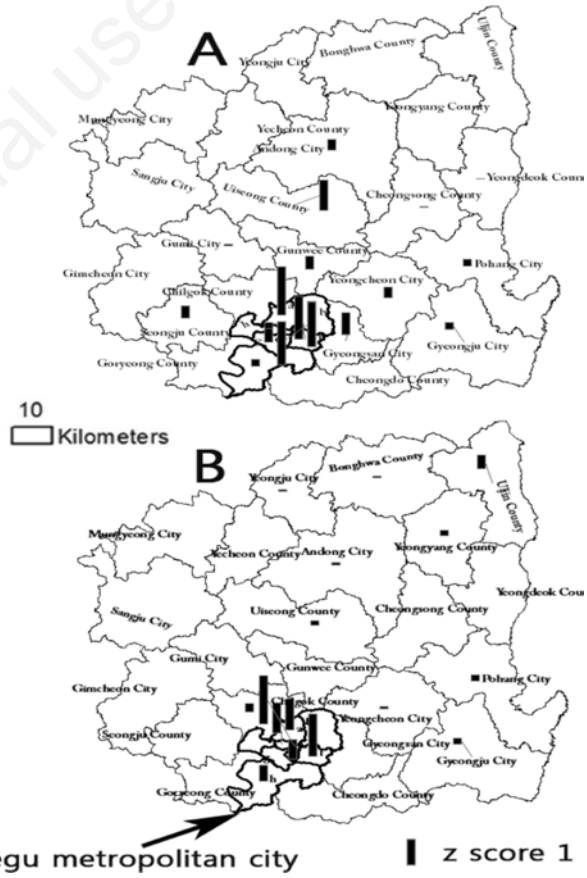

Figure 2. Spatial cluster map of chronic sleep deprivation prevalence: A) men; B) women. A high positive z-score for a feature indicates that the surrounding features have similar values (either high or low values), while a low negative z-score (*e.g.*, <-1.96) indicates a statistically significant (P=0.05) spatial outlier. In Daegu Metropolitan City: a) Buk District; b) Dong District; c) Seo District; d) Nam District; e) Jung District; f) Suseong District; g) Dalseo District; h) Dalseong District.

severely impaired mental or physical health may not be good interviewees and are thus excluded from the survey. Sleep has both qualitative and quantitative aspects. Due to data limited to total sleep time, the present study examined basic patterns of sleep hours among elderly individuals in Korea using available data. The results of this research do not directly correspond to the information needed to improve sleep quality. More detailed data, including sleep initiation (ability to fall asleep within a reasonable amount of time) and sleep maintenance (*e.g.*, the number of arousals, depth, and restfulness of sleep) are required to judge good or poor sleep quality, although it is generally agreed that people with sleep insufficiency often have poor sleep quality. Lastly, the analysis involved residents of a single province in Korea, Gyeongbuk, one of the most diverse communities in the country; the results cannot therefore be generalised.

Chronic sleep deprivation hotspots in metropolitan urban communities provide an ideal opportunity for comparing CSD-related policies to develop plausible explanations of the causes of differences in CSD prevalence rates. Low-CSD communities in suburban areas adjacent to high-CSD communities in metropolitan areas may be at risk of developing CSD problems because of urban sprawl and thus require early prevention strategies. An increase in the sleep time for individuals with CSD is likely to require community-based behavioural strategies (*e.g.*, environmental stress) rather than clinical settings such as those aimed at various sleep disorders (*e.g.*, insomnia and sleep apnoea).

Conclusions

Chronic sleep deprivation prevalence may increase as communities adopt more urban lifestyles. The results of this study indicate that metropolitan urban living may be a major risk factor in CSD. To our knowledge, this is the first study to comprehensively investigate CSD hotspots in an elderly population by using large and comparable population-based data sets from several urban and rural communities based on a Korean sample. The large sample used allowed assessment of the variability of CSD prevalence at a community level (metropolitan urban, rural, and industrial areas). Although further research is required, the results provide an initial methodological framework for examining spatial hotspot patterns of CSD prevalence in the context of regional and local communities.

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