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Age and gender differences in linkages of sleep with subsequent mortality and health among very old Chinese

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Abstract

Background—Studies suggest that sleep quality and duration are significantly associated with mortality risk and health conditions, yet such studies are seldom conducted among very old adults. The objective of this study was to examine associations between self-reported sleep quality/duration and subsequent mortality/health among very old adults in China. A second objective determines whether these associations vary by age and gender.

Methods—This study used data of the 2005 and 2008 waves from a large, representative survey with a total of 12,671 individuals in 22 provinces in mainland China, in which 3158 respondents were aged 90–99 and 2293 were centenarians. Two self-reported questions about sleep quality and duration were examined while adjusting for numerous socio-demographic, family/social support, health practices, and baseline health factors.

Results—Hazard regressions showed that, when demographic factors are controlled for, Chinese elders who report poor and fair quality of sleep have 26% and 10% higher risk of death over the next three years compared to those with good sleep quality; those who sleep either 6 h or less or 10 h or more per day have an 18–22% higher mortality risk as compared to those who sleep 8 h per day. The increased mortality risks of poorer sleep and too short or too long sleep duration are larger in men than in women and more robust in the oldest-old than in young elders. Logistic regressions show that poor sleep and daily sleep durations of 5 h or less or 10 h or more are also associated with worse health three years later.

Conclusions—Poorer sleep quality and too short or too long sleep duration are associated with higher subsequent mortality risk and lower odds of being in a healthy state among very old Chinese.

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Ethical approval

Duke University Health System's Institutional Review Board (IRB) reviewed and approved ethics for this study.

Authors' contributions

Li Qiu conducted the analysis, drafted and revised the paper. Jessica Sautter drafted and revised the paper. Yuzhi Liu prepared the data. Danan Gu initiated and designed the study, supervised the analysis, and drafted and revised the paper. D. Gu has the full access to the dataset and is responsible for the accuracy of the results.

Conflicts of Interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: doi:10.1016/j.sleep.2011.04.014.

Keywords

China; Healthy longevity survey; Mortality; Gender differentials; Older adults; Oldest-old; Quality of sleep; Sleep duration

1. Introduction

Accumulating evidence in the literature suggests that good quality of sleep is an important factor in reducing the risk of mortality and health decline in later life [1]. The literature also suggests that quantity of sleep is an important factor associated with health and mortality. For instance, insufficient or excessive sleep duration is an important risk factor for poor mental and physical health-related quality of life at older ages [2]. Some large, longitudinal, age-heterogeneous studies have concluded that deviations above and below 7–9 h of sleep per night are associated with increased mortality, producing a U-shaped association between hours of sleep and mortality risk [3–9].

The causality of the association between sleep and health is unclear, however. On one hand, poor health could cause some organic pathological problems and thus cause poor sleep quality or shorter or excessive sleep duration. For instance, self-reported sleep problems are significantly greater among those with higher levels of depression/anxiety [10], chronic illnesses [10–12], mental illness [10,12,13], poor self-rated health [10,12,14], and poor functional status [15]. On the other hand, poor sleep quality and deviation from a sleep duration of 7–8 h may cause poor health [3,16,17]. There is evidence showing that improving sleep quality among the elderly can improve their health and quality of life [18], and interventions recognizing the importance of improving sleep quality have been successful among older adults [2,19]. Overall, the causal direction between sleep problems and health can be bidirectional. Furthermore, it is largely unknown whether the association between sleep and health mediates the association between sleep and mortality.

The literature has identified important associations and possible explanations between sleep quality and duration in old age and their associations with subsequent health and mortality. Yet, age patterns of these associations among the oldest-old, aged 80 and older, remain largely unknown, because most studies rely on data that lack relatively large samples of the oldest-old [20]. Only recently have we started to understand sleep patterns at very old ages [21], which provide important insights into healthy longevity among nonagenarians and centenarians.

Gender differences in quality of sleep are relatively consistent across studies, with women having more sleep problems compared to men [10,12–14]. However, gender differences in associations between sleep problems and subsequent mortality/health are inadequately studied, especially in the elderly population [8,21–25]. Although two studies find a stronger association between sleep quality(insomnia)/duration and mortality/health in men than in women [8,25], most studies consistently find a stronger association between sleep quality and mortality/health in women than in men. Age differences in associations between sleep and mortality/health are even less studied than gender differences. One study found that the general patterns of associations between sleep quality/length and mortality across age groups were more or less similar [8]. There is also a paucity of studies examining sleep quality and duration among the elderly from China, a country with the largest elderly population in the contemporary world. So far, with one exception [26], only a few locally-based studies with small sample sizes have investigated sleep issues among the elderly in mainland China [14], Hong Kong, and Taiwan [16,27,28]. It is unclear whether the empirical findings in Western countries will hold in mainland China, an Eastern developing country. There are some demonstrated differences in sleep patterns between the East and West; for example, Chinese elders have earlier average waking and bed times than their Western counterparts [14]. Finally, with few exceptions [26,29,30], many studies model sleep duration as a continuous variable [13,31,32] and do not examine possible non-linear associations between sleep quality or duration and health outcomes.

Our research aims to investigate sleep quality and duration and their associations with subsequent health condition and mortality by using data from a nationally representative population-based survey of mainland China with what is currently the largest sample of centenarians and nonagenarians in the world.

2. Methods

2.1. Study population

This study used data from the 2005 to 2008 waves of the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The CLHLS, which began in 1998, is the first nation-wide longitudinal survey focusing on the oldest-old ever conducted in a developing country. Interviews were conducted in randomly-selected halves of the counties/cities in 22 out of the 31 provinces in China. The total population in these 22 provinces covered 85% of China's total population in 2000. Among the 22 sampled provinces, 21 provinces are predominantly Han Chinese who normally have high accuracy in age reporting; one province is predominantly made up of individuals of the *Zhuang* ethnicity, who, over the years, have been culturally and residentially integrated with the Han [33]. The CLHLS aimed to interview all centenarians in the sampled counties/cities (about 851 counties/cities in the 2005 wave) with informed consents. Lists of centenarians were provided by the local Residential Committees in urban areas or the local Village Committees in rural areas. Age of each centenarian was validated from various sources as available, including birth certificate, geological documents, household booklet, age of their children and siblings [33]. For each centenarian interviewed, one nearby octogenarian and one nearby nonagenarian with pre-designated age and sex were randomly chosen to be interviewed based on a random code assigned to the centenarian. If the random code assigned to a centenarian was an even number, a female octogenarian and a female nonagenarian were interviewed (odd numbers indicated male respondents). The ages of both the octogenarian and nonagenarian respondents were pre-designated to match the last digit of the random code of the centenarian. If there were no such appropriate octogenarians or nonagenarians available in the village or street of the sampled centenarian, the CLHLS team recruited respondents nearby. The term "nearby" refers to the same village or street, or the same town, county, or city, when applicable. This sampling strategy was designed to ensure comparable numbers of randomly selected male and female octogenarians and nonagenarians at each age from 80 to 99. The CLHLS is very representative of the elderly population in Mainland China; distributions of key variables are close to those in other nation-wide surveys. The CLHLS dataset contains a weight variable that reflects the sampling design and ensures that the weighted sample distributions match those in the population in the twenty-two sampled provinces in terms of age, sex, and urban–rural residence.

We use the 2005 and 2008 waves of the CLHLS because they included questions on self-reported sleep quality and duration. The 2005 wave interviewed 15,638 individuals aged 65 and older, with 5047 young seniors aged 65–79 and 10,591 oldest-old seniors aged 80 and older (3870 octogenarians, 3927 nonagenarians, and 2794 centenarians); 6688 respondents were men, and 8950 were women. The response rates in both waves were around 90%. Duke University Health System's Institutional Review Board (IRB) reviewed and approved ethics for this study and informed consent was obtained from the patients. By the follow-up wave three years later, out of these 15,638 respondents, 7472 (47.8%) survived to the 2008 survey, 5199 (33.25%) died before the 2008 survey, and 2967 (19.0%) were lost to follow-up. Those lost to follow-up were excluded as we did not know their survival status and health conditions in 2008, which leaves 12,671 respondents in this analysis.

In addition to data on self-rated sleep quality and hours of sleep, the 2005 and 2008 waves collected data covering demographic characteristics, family and household characteristics, lifestyle, diet, psychological characteristics, economic resources, self-reported health, self-reported life satisfaction, lower and upper extremities performance, instrumental activities of daily living (IADL), activities of daily living (ADL), cognitive functioning, and chronic diseases. All information was obtained through in-home interviews. The date of interview was recorded at both waves. For those who died before the 2008 interview, the date of death and other information were collected from officially issued death certificates whenever available; next-of-kin and local Residential Committees were consulted in cases when death certificates were not available. The high accuracy of age reporting and high quality of other variables in the CLHLS have been documented elsewhere [33,34].

2.2. Sleep measurements

The 2005 and 2008 waves of the CLHLS included one self-rated question about self-rated global sleep quality: "how do you rate your overall sleep quality recently?" Response categories included: very good, good, fair, poor, and very poor. Unlike some other studies that use a well-established sleep quality index [35], the CLHLS only included one general question on sleep quality, which is similar to Question 6 in the Pittsburgh Sleep Quality Index [35]. A similar rating scale has been used in previous research [6]. The category of "very good' in the CLHLS indicates no trouble falling asleep within 20 min or waking up during sleep regardless of use of sleep medicine. We classified the sleep quality measure into good (good/very good), fair, and poor (poor/very poor), with poor as the reference. The CLHLS also included one self-reported question about daily hours of sleep in 2005 and 2008: "how many hours on average do you sleep every day, including napping?" In order to capture possible non-linear associations between sleep duration and health outcomes, we followed a categorization used by three previous studies [20,23,24] and classified sleep hours into ≤five, six, seven, eight, nine, and ≥ten. We used the category of eight hours as the reference category because it is the mode in the weighted sample (see Table 1), which is also consistent with a previous study [26], and because eight hours of sleep was associated with one of the lowest risks of mortality.

2.3. Outcome variables

Two outcome variables were analyzed in this study. One was mortality risk and the other was health condition. Mortality risk was analyzed by the survival analysis described below. Health condition was measured by a cumulative health deficit index, a measure that has become increasingly popular in aging studies [36–38]. Following established research [36–38], we defined the cumulative health-deficit index as an unweighted count of the number of deficits divided by the total number of possible deficits for a given person. We used 39 indicators of self-reported health, cognitive functioning, disability, auditory and visual ability, depression, heart rhythm, hypertension, stroke/cardiovascular disease, heart disease, diabetes, tuberculosis, arthritis, and numerous other chronic diseases that were collected in 2005 and 2008. The items comprising our cumulative health-deficit index are similar to those used in studies from Canada [38], the United States [37], and Hong Kong [39]. We dichotomized individual items and coded them as one when a deficit was present. Consistent with prior research, we assigned a score of two if the respondent had a serious illness that caused him or her to be hospitalized or bedridden two or more times during the last three years [39]. We then computed the deficit index by summing all deficits and dividing by the total number of possible deficits (range = 0 ~ 1). A lower deficit index score indicates a healthier status. The validity of the health deficit index in the CLHLS datasets has been verified elsewhere [36]. The list of detailed variables used to construct the health deficit index is also published elsewhere [36]. We used the lowest quartile of the deficit index to classify the respondents as healthy. Other alternatives such as the lowest tertile, quintile, and decile of the index only altered the results slightly.

2.4. Covariates

To obtain robust results, we controlled for numerous confounders that have been associated with sleep quality and hours of sleep in previous studies [29,30], as well as those associated with health and mortality [40,41]. These factors included demographic, socioeconomic status (SES), family/social connections, and health practices. Demographic variables included chronological age, sex, ethnicity (Han vs. Non-Han), and urban/rural residence (urban vs. rural). We measured SES with education (1 + years of schooling vs. 0), self-reported family economic condition (good vs. other, as compared to other families), and access to healthcare when in need (yes vs. no). We measured social connection/support with current marital status (married vs. no), number of living children, and living arrangements (classified as living alone, living with spouse or family, or living in an institution). Health practices included whether the respondent was a smoker (yes vs. no) and whether the respondent was an alcohol user (yes vs. no) at the time of the survey. We further tested for geographic differences.

3. Statistical analysis

We used survival analysis to investigate the associations between sleep and mortality. The dependent variables in survival analyses are survival status (died or survived in the 2008 wave) and duration of survival (measured in days). We used parametric Weibull hazard regression because some covariates violate the proportionality assumption for hazards. The sample for these analyses excludes respondents who were lost to follow-up in 2008; the valid sample size in survival analyses includes 12,671 respondents consisting of 7250 women, 5421 men, 4057 young elders aged 65–79, and 8614 oldest-old. We constructed three sequential models for Weibull hazard regressions: Model I looked at the effect of age on sleep quality and duration, controlling for other demographics and geographic location; Model II further controlled for socioeconomic status, social connection, and health practices; Model III further controlled for health condition (i.e., cumulative health deficit index) in 2005.

We used logistic regression to investigate associations between self-rated sleep quality and self-reported duration in 2005 and subsequent health condition in 2008. We employed three sequential models in ordered logistic regressions that are similar to those in survival analysis. We also investigated a reciprocal model, associations between health condition in 2005 and sleep quality and sleep duration in 2008. For this analysis we used two sequential models similar to Model I and Model II in the survival analysis. The sample for these analyses only includes respondents who survived to the 2008 wave. That is, it excludes those who were lost to follow-up in 2008 or died between these two survey intervals. The valid sample size in ordered logistic regressions is 7472 respondents consisting of 4119 women, 3353 men, 3575 young elders aged 65–79, and 3897 oldest-old.

To reduce possible bias in our data analysis and inference due to missing items (although only about 2% of the data are missing for any variable), we imputed the variable mean for missing continuous variables and the variable mode for missing categorical variables [42]. We also tested other imputation approaches (such as mean, median, mode, and other simple regression) that yielded similar results. Given that the sampling weight variable in the publicly released CLHLS dataset is calculated based on the age–sex–urban/rural residencespecific distribution of the population and does not capture other important compositional variables, such as marital status, economic status, etc., we did not apply sample weights in the regression analyses. Research has shown that including variables related to sample selection in the regression produces unbiased coefficients without weights; additionally, weighted regression results are likely to enlarge the standard errors [43]. However, we did apply the weight in cases when we referred to the general elderly population. We performed all analyses using STATA 10.1.

4. Results

Table 1 presents variable distributions for the mortality analysis sample and for the health analysis sample separately. Table 1 also shows that the weighted prevalence of reporting good sleep quality is approximately 65%, the weighted mode of sleep duration is eight hours (27.8%), and the weighted average sleep duration is 7.5 h (SD = 1.9).

Table 2 presents the distribution, by level of sleep quality and quantity, of death between 2005 and 2008 and of being in a healthy condition (lowest quartile of the cumulative deficit index) in 2008. The observed relative frequencies (both weighted and unweighted) in Table 2 show that elders who have good sleep quality have a lower proportion of death and higher proportion of being in a healthy condition three years later as compared to those whose sleep quality was poor. Both the mortality difference and the health difference by sleep quality are greater in men and in the oldest-old than in women and in young elders. Persons who slept 7–9 h per day had a lower proportion of death and a higher proportion of being in a healthy condition when compared to persons whose sleep duration was less than seven or more than nine hours. Gender and age differentials in death and health by sleep duration are similar to those by sleep quality.

The left panel in Table 3 shows that, in the full sample, those who reported poor quality of sleep and those who reported fair quality of sleep had a 26% (HR = 1.26, 95% CI: 1.15–1.38) and 10% (HR = 1.10, 95% CI: 1.04–1.18) higher risk of death than those who reported good quality of sleep, respectively, after controlling for age, ethnicity, urban–rural residence, and geography (Model I for total). Analyses by gender and age further revealed that the increases in mortality risks associated with poor or fair quality of sleep were only found in men (55% [HR = 1.55, 95% CI: 1.33–1.79] and 17% [HR = 1.17, 95% CI: 1.06–1.30]) and in the oldest-old (25% [HR = 1.25, 95% CI:1.14–1.38] and 11% [HR = 1.11, 95% CI: 1.03–1.18]). Such increased risks were not statistically significant among women and young elders. The increased risks in mortality among men and the oldest-old were attenuated after taking SES, social/family support, and health practices into account. After baseline health was taken into account, the increased risks of poorer quality of sleep in mortality were no longer significant.

The right panel of Table 3 further shows that, in the full sample, persons who slept five hours or less, six hours, or ten hours or more per day had a 19% (HR = 1.19, 95% CI: 1.08–1.32), 18% (HR = 1.18, 95% CI: 1.07–1.30), and 22% (HR = 1.22, 95% CI: 1.13–1.32) higher risk of death, respectively, as compared to those who slept eight hours when only age, ethnicity, urban–rural residence, and geographic location were controlled for. There was no difference in mortality risk between sleeping seven hours and eight hours and between nine hours and eight hours (Model I for total), indicating that sleep durations of 7–9 h had the lowest mortality risk. These patterns by sleep duration were mostly unaltered when SES, social/ family support, and health practices were further adjusted for (Model II for total). However, when baseline health (i.e., health condition in 2005) was additionally controlled for, only the category of ten hours or more was significantly associated, with 9%

(HR = 1.09, 95% CI: 1.00–1.18) higher risk of death compared to the category of eight hours (Model III for total).

Gender differences by sleep duration were substantial, although, on average, both men and women who slept 7–9 h had the lowest mortality risk. For example, in men, sleep durations other than eight hours were associated with 20–47% higher risk of death when only demographic factors were controlled (Model I for men); an exception was nine hours of sleep, which was not significantly different from eight hours. In women, only those who either slept six hours or ten hours or more had a 12–14% higher risk of mortality compared to those who slept eight hours (Model I for women). Hazard ratios for both genders were only slightly attenuated when SES, social/family support, and health practices were further taken into consideration, although these factors mediated the association between six vs. eight hours of sleep and mortality for women (Models II for men and women). Once baseline health was included in the model, higher risks of mortality associated with durations other than eight hours in women disappeared (Model III for women), whereas in men two extreme categories still had 17% (RH = 1.17, 95% CI: 1.01–1.38) (for 5h or less) and 22% (HR = 1.22, 95% CI: 1.08–1.38) (for 10 h or more) higher risk of mortality as compared to sleep duration of eight hours (Model III for men).

Age differences by sleep duration were also pronounced. Among the oldest-old, those who slept five hours or less, six hours, or ten hours or more had 18–21% higher risks of mortality as compared to those who slept eight hours (Model I for Ages 80+). However, these associations were not statistically significant in young elders except for the category of ten hours or more in which elders had a 46% (HR = 1.16, 95% CI: 1.11–1.91) higher risk of death as compared to elders who slept eight hours (Model I for ages 65–79). Results further suggested that SES, social/family support, and health practices did very little to mediate the association between sleep duration and mortality (Models II). When baseline health was additionally controlled for in Model III, there were no significant differences across different sleep hours. Again, the lowest mortality risks were observed for sleep durations of 7–9 h.

Table 4 presents odds ratios for being in a healthy condition in 2008, measured by the lowest quartile of the cumulative health deficit index. The results reveal that elders who reported poor and fair sleep quality had 37% (OR = 0.63, 95% CI: 0.51–0.77) and 28% (OR = 0.72, 95% CI: 0.63–0.83) lower odds of being in a healthy state compared to those who reported good sleep, controlling for demographics (Model I for total). In Model I, large age and gender differences were evident: associations between sleep quality and subsequent health were stronger for men and the young–old compared to women and the oldest-old. For instance, men who reported poor and fair quality of sleep had 59% (OR = 0.41, 95% CI: 0.29–0.57) and 33% (OR = 0.67, 95% CI: 0.55–0.81) lower odds of being in a healthy state, respectively, compared to those reporting good sleep; young elders who reported poor and fair sleep quality had 42% (OR = 0.58, 95% CI: 0.46–0.72) and 28% (OR = 0.72, 95% CI: 0.61–0.85) lower odds of being in a healthy state as compared to those reporting good sleep. With few exceptions, there were almost no statistical differences in the odds of being in a healthy state by sleep quality among women and the oldest-old. In most cases, the distinction between poor and good sleep quality was stronger than that between fair and good sleep quality. The lower odds of being in a healthy state for poor or fair sleep quality compared to good sleep quality were only slightly attenuated when SES, social/family support, and health practices were further controlled for; age and gender differential patterns remained valid. The inclusion of baseline heath in Model III mediated the association between sleep quality and the odds of being in a healthy state, except among men, for whom poor sleep quality was associated with 35% (OR = 0.65, 95% CI: 0.46–0.93) lower odds of being in a healthy state three years later as compared to men who reported good sleep quality.

Model I in the right panel of Table 4 shows that those who reported sleep durations of five hours or less and ten hours or more had 34% (OR = 0.66, 95% CI: 0.54–0.80) and 22% (OR = 0.78, 95% CI: 0.66–0.93) lower odds, respectively, of being in a healthy condition three years later. Gender and age differences were substantial. For women, sleep durations of five hours or less, nine hours, and ten hours or more had 33% (OR = 0.67, 95% CI: 0.51–0.88), 30% (OR = 0.70, 95% CI: 0.49–0.99), and 32% (OR = 0.68, 95% CI: 0.52–0.89) lower odds of being in a healthy state compared to the sleep duration of eight hours when only demographic factors were controlled (Model I for women). For men, only those who slept five hours or less had, significantly, 37% (OR = 0.63, 95% CI: 0.47–0.83) lower odds of being in a healthy state compared to those who slept eight hours (Model I for men). For young elders, those who slept five hours or less were 41% (OR = 0.59, 95% CI: 0.47–0.75) less likely to be in a healthy state compared to those who slept eight hours when only demographic factors were present. There was no difference in reduction in odds of being in a healthy state across other categories of sleep in young elders. For the oldest-old, the sleep duration patterns were less clear. The results showed that those who slept seven hours or slept ten hours or more tended to have significantly lower odds of being in a healthy state compared to those who slept eight hours. In general, 7–9 h of sleep was associated with the highest odds of being in a healthy state three years later. Further controlling for SES, social/family support, and health practices only slightly changed the results. However, when baseline health was included in the model, associations between sleep and subsequent health were no longer significant.

To investigate the direction of association, we also conducted an analysis examining how baseline health affected subsequent sleep quality and sleep duration three years later. Our results (not shown, but available upon request from authors) indicated that those in the lowest deficit index quartile (i.e., healthiest persons) in 2005 had 85% higher odds of having good sleep quality versus fair/poor sleep quality in 2008 compared to those in the highest quartile (i.e., least healthy persons) after controlling for demographics, SES, family/social support, and health practices. Those in the healthiest quartile in 2005 had 53–66% higher odds of reporting 7–9 h of sleep per day in 2008 compared to those in the least healthy quartile. Interestingly, the relationship between health in 2005 and sleep quality in 2008 was stronger among men and among the young elders, whereas the relationship between health in 2005 and sleep duration in 2008 was more stable and greater in women and the oldest-old.

5. Discussion

We investigated age and gender differences in associations between self-rated sleep quality and self-reported duration and subsequent mortality and health with a large population-based longitudinal survey among very old persons in mainland China. We showed that, compared to persons who reported good sleep quality, those who reported poor and fair quality of sleep had a 26% and 10% higher risk of death, respectively, when only demographic factors were controlled; SES, family/social support, and health practices had only small effects on these associations. Those who reported sleep duration of 7–9 h per night had the lowest risks of death. Compared to eight hours of sleep, those who reported five hours of sleep or less or ten hours of sleep or more had 18–22% higher risks of mortality when we controlled for demographic factors; these higher risks were not altered when SES, social/family support, and health practices were further adjusted, which suggests that sleep that is too short or too long was associated with increased risk of death. Controlling for health status in 2005 did mediate many associations between sleep and health/mortality, an issue that we will come back to it later. These associations were stronger for men and the oldest-old than for women and young elders. Good sleep quality was also associated with better subsequent health, with more robust associations in men than in women, and in young elders compared to the oldest-old. Our results further showed that too short (five hours or less) or too long (ten hours or more) sleep duration per day were associated with decreased odds of subsequent good health. In summation, our results confirm and extend the findings of previous research that has not been able to adequately focus on very old adults [1,3,16]. To our knowledge, this study was the first to use nationally representative data to examine the associations between sleep and subsequent mortality and health in exceptionally long-lived persons and to look at age and gender differences in these associations.

One interesting finding was that gender did moderate the associations between sleep and mortality and health, with a stronger association between sleep quality/length and mortality/health in men than in women, which is consistent with some previous studies [8,25]. However, the gender difference in our study was opposite to findings in other studies [21–24]. Speculations about this difference were mainly derived from differences in physiological, psychosocial, and pathophysiological mechanisms between men and women. The stronger association in men in our analysis may have been due to several reasons. First, unlike previous studies that mainly focused on young adults [21–24], respondents in our sample were very old. Previous studies have shown different sleep mechanisms across age groups [44]. Thus, the age composition of our sample may contribute to gender difference. Second, elderly men and women may use different criteria to rate subjective sleep quality. For example, elderly men's subjective sleep quality largely reflects their objective sleep quality, while women's objective and subjective sleep quality tends to be different [45]. Third, although Chinese elderly women in this sample had more sleep problems than men, this was similar to findings in most other populations [26]. Chinese women have less psychological distress than their male counterparts [46]. Studies have shown that sleep disturbances are more strongly associated with depression in women than in men. Women may also adapt more easily to their medical burden than do men, and therefore be less likely to report depression resulting from chronic conditions, and, in turn, be less likely to report sleep disturbance associated with chronic conditions [47]. Fourth, our analysis omits some important confounders such as BMI and/or use of sleep drugs, as we describe in more detail below. All these factors alone or in combination may have contributed to our finding that associations between sleep and health/mortality were more pronounced in men than women. We of course welcome more research on this gender difference.

One other interesting finding of the present study was the stronger association between sleep quality/duration and mortality found in the oldest-old compared to young elders. One previous study suggested that patterns in associations between sleep quality/ duration and mortality are similar across different age groups (ages < 40, ages 40–54, and ages ≥55) for both men and women [8], whereas another study showed that the relationship between sleep duration and mortality among an elderly population aged 60–86 was different from that among adults aged 32–59 [6]. We speculate that the stronger associations of sleep with mortality found in the oldest-old in our study may be linked to reduction in amplitude and increase in frequency of delta waves at very old ages, both of which are closely related to sleep quality [44]. In contrast to the stronger relationship between sleep quality and mortality among the oldest-old, our results also showed that the association between sleep quality and subsequent health was stronger among young elders than among the oldest-old. This result was unexpected. We speculate it may have been related to a significant diminishment in well-being and life satisfaction, which resulted from changes in the social network around retirement ages [48]. As there is very limited evidence concerning differences in associations between sleep/duration and mortality/health by age groups among very old adults, we call for more studies to articulate the contradictory phenomenon.

Unlike previous studies, which focused on a single dimension of health, we created a comprehensive measure of overall health conditions, the cumulative health deficit index, by combining 39 health indicators. These indicators measured multidimensional domains of health, including self-reported health, cognitive functioning, psychological well-being, and disabilities. The cumulative health deficit index has been recognized as a new measurement for health among researchers and is becoming more influential [49]. We believe this application has a potential value in addressing the overall association between sleep and health/mortality, since researchers are frequently challenged by residual confounders and co-morbidities when addressing the associations between sleep and subsequent mortality and health [2–4].

Although the underlying mechanisms between sleep quality/ duration and subsequent mortality/health are not clear, it has been recognized that insufficient or poor quality of sleep can exert deleterious effects on a variety of systems, with detectable functional deterioration in metabolic, endocrine, and immune pathways [2,4,50–52]. A number of experimental studies have shown that short sleep causes potentially adverse endocrinologic, immunologic, and metabolic effects [51,52]. Furthermore, as sleep patterns of quantity and quality are affected by a variety of cultural, social, psychological, behavioral, pathophysiological, and environmental influences [11,14], it is very difficult to disentangle the underlying mechanisms. Further research focusing on the mechanism between sleep and health/ mortality is clearly warranted.

Another interesting finding is that baseline health plays a major role in mediating the associations between sleep and both subsequent health and mortality in the short term. This is likely because baseline health status is an overwhelmingly strong predictor of subsequent health status and mortality, thereby dwarfing any small associations with sleep quality and duration. Indeed, many social epidemiological studies focusing on associations between SES and mortality frequently find that baseline health greatly modifies the associations between SES and mortality [13,19,41,53,54]. Although the mediation association in the present study is different from those found in epidemiology, the underlying principle of mediation is likely the same. It may also be possible that the short length of the follow-up period (three years) is not sufficient to detect the differences in subsequent mortality and health outcomes when we assume that everyone has the same health condition at baseline. We welcome additional research to further shed light on the role of baseline health in determining the relationships between sleep quality and duration and health and mortality at late ages.

A number of studies in the literature have reported that the relationships between health and sleep are bi-directional. That is, on one hand, good health can improve sleep quality and maintain 7–9 h per day [10,12]; on the other hand, good sleep can enhance health condition [7,55]. Our analyses support the bi-directional relationship argument. In other words, sleep and health are highly endogenous. The interplay of these two items is likely complicated and deserves more research.

Several limitations of this study should be taken into account when interpreting the results. First, the data on sleep quality and sleep duration in the CLHLS were self-reported. Although subjective evaluation of sleep is likely to be important, this type of measure is not standardized due to different questions asked by different investigators in surveys, which may limit comparability with other studies. More importantly, subjective measures and some objective measures, such as actigraphy, may yield different results [56]. Second, relevant to the first, the present study examined very basic patterns of sleep quality and hours among Chinese elders. More detailed questions, including data on the duration, frequency, or severity of the sleep problems suffered by older adults, would be informative. Third, use of sleep medication (both Western and Chinese herbal/botanical), sedative–hypnotic medication, and data on sleep apnea were not measured in the CLHLS. Thus, we were unable to distinguish between people who had sleep problems that were corrected by sleep medications or other drugs that affect sleep and people who did not have sleep problems.

Given that use of medication is associated with quality of sleep [14,57,58], this mixture of corrected and non-corrected sleep patterns might introduce some bias into the estimates. For example, medications not specifically prescribed for sleep, such as anti-cholinergic medications for incontinence and ulcers, affect both sleep and cognitive performance; however, one study shows that there is still a significant relationship between sleep quality and cognition after controlling for potentially confounding factors such as medication use, cerebrovascular disease, and depression [17]. Empirical studies have shown that approximately 3–7% of seniors in China use sleep medicines, with the majority using diazepam [14]. Furthermore, although apnea is strongly associated with some morbidities [59], some prior research has reported that both symptoms of sleep apnea and frequent hypnotic drug use do not have power in predicting mortality [60]. Thus, our inability to control for medication use and apnea might not be very harmful to our general conclusions due to low prevalence and impact on health and mortality. Nevertheless, further research that controls for these confounders is warranted. Fourth, we did not include body mass index as a covariate in the model because the necessary data were not available in the 2005 wave. Western studies have shown that sleep quality or duration is related to obesity [24,51,52]. Omission of the body mass index information may introduce some biases. Fifth, some environmental factors (such as noise, air pollution, and so forth) might be associated with sleep quality and even mediate the relationships between sleep and mortality/ health. Integration of these factors into analysis is rare in the existing literature, but might have important implications for sleep intervention through environmental improvement. Finally, there are around 20% of respondents who were lost to follow-up. The loss of these respondents may bias the results.

In spite of these shortcomings, we have extended the existing research by providing new estimates of sleep quality, duration, and their association among a unique, large sample size of oldest-old adults from a developing country where the population of elders grows fast and their sleeping problems are largely unknown. The results of this study help us understand age and gender patterns of quantity and quality of sleep and their associations with subsequent mortality health status among exceptionally long-lived adults.

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Table 1

Sample distribution by sleep quality, duration, and other study variables.

	Mortality analysis sample					Health analysis sample				
	Women	Men	Ages 65–79	Ages 80+	Total	Women	Men	Ages 65–79	Ages 80+	Total
Sample size	7250	5421	4057	8.614	12,671	4119	3353	3575	3897	7472
% Good sleep	60.7	68.3	65.1	63.4	63.9 (65.0)	61.0	71.1	65.6	65.4	65.5 (65.7)
% Fair sleep	27.5	22.7	23.0	26.6	25.5 (23.1)	26.8	21.3	22.9	25.6	24.3 (22.9)
% Poor sleep	11.8	9.0	11.9	10.0	10.6 (11.9)	12.2	7.6	11.5	9.0	10.2 (11.4)
% Sleeping hours 5 or less	13.2	11.8	13.4	12.2	12.6 (13.4)	14.1	11.0	13.2	12.3	12.7 (15.0)
% Sleeping hours 6	15.3	14.0	16.2	14.1	14.7 (16.1)	15.5	14.3	16.3	13.8	15.0 (17.6)
% Sleeping hours 7	13.6	14.3	18.8	11.5	13.9 (18.4)	16.0	15.6	19.0	12.9	15.8 (19.3)
% Sleeping hours 8	20.9	25.1	28.1	20.3	22.8 (27.8)	23.2	28.8	28.5	23.0	25.6 (26.0)
% Sleeping hours 9	6.9	8.6	9.0	7.0	7.6 (9.1)	7.8	9.7	9.2	8.2	8.7 (7.7)
% Sleeping hours 10 or more	30.1	26.0	14.5	34.9	28.4 (15.2)	23.4	20.7	13.8	29.8	22.2 (14.4)
Average sleeping hours per day	8.1	8.0	7.4	8.4	8.1 (7.5)	7.7	7.8	7.4	8.1	7.8 (7.4)
% Death	43.2	38.1	11.9	54.8	41.0 (13.5)	–	–	–	–	–
Mean score of cumulative health deficit index in 2008	–	–	–	–	–	0.24	0.18	0.13	0.29	0.22 (0.14)
Mean Age	88.1	83.4	71.8	92.8	86.1 (72.5)	82.8	79.4	71.6	90.2	81.3 (71.9)
% Urban	40.8	42.1	40.4	41.8	42.4 (39.1)	40.7	41.9	40.5	42.0	41.3 (39.1)
% Han ethnicity	92.7	93.3	93.7	92.6	93.0 (93.6)	92.7	93.4	93.7	92.5	93.1 (93.6)
% 1 + years of schooling	17.8	64.2	54.4	29.8	37.7 (52.6)	22.3	67.8	53.6	31.9	42.8 (53.5)
% Good family economic condition	14.0	17.4	15.3	15.6	15.5 (15.0)	14.5	18.7	15.2	17.4	16.4 (15.2)
% Got adequate medical service	86.9	89.4	90.0	87.0	88.0 (90.0)	88.4	90.8	90.4	88.6	89.5 (90.6)
% Married	18.6	50.8	64.5	17.2	32.4 (61.9)	27.5	60.8	65.0	21.8	42.5 (63.2)
Average No. of living children	3.5	3.7	3.9	3.4	3.6 (3.9)	3.7	3.8	3.9	3.6	3.7 (3.9)
% Current smoker	7.1	36.2	28.7	15.2	19.7 (27.7)	7.9	40.5	28.9	16.8	22.6 (28.1)
% Current alcohol consumer	11.3	32.7	24.6	18.5	20.4 (24.4)	11.3	36.1	25.1	20.0	22.4 (25.0)
Mean score of cumulative health deficit index in 2005	0.24	0.16	0.10	0.26	0.21 (0.10)	0.17	0.12	0.09	0.19	0.14 (0.09)
% North	5.5	5.7	5.8	5.5	5.6 (5.7)	5.4	6.2	5.9	5.6	5.8 (5.9)
% Northeast	7.6	9.8	10.5	7.6	8.5 (11.1)	8.4	9.8	10.6	7.8	9.1 (10.4)
% East	36.4	37.1	36.8	36.7	36.7 (36.8)	36.5	36.8	36.9	36.4	36.7 (36.7)
% Central/South	34.8	32.0	31.7	34.5	33.6 (31.9)	34.5	31.8	31.5	34.9	33.3 (31.8)

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	Mortality analysis sample					Health analysis sample				
	Women	Men	Ages 65–79	Ages 80+	Total	Women	Men	Ages 65–79	Ages 80+	Total
% West	15.7	15.4	15.3	15.7	15.6 (15.5)	15.2	15.3	15.2	15.3	15.3 (15.3)
% Live alone	14.5	12.1	12.6	13.9	13.5 (12.6)	16.2	11.6	12.7	15.4	14.1 (12.5)
% Live with spouse or family	83.0	85.6	86.4	83.0	84.1 (86.3)	92.0	86.7	86.4	82.0	84.1 (86.6)
% Live in an institution	2.5	2.4	1.0	3.1	2.5 (1.1)	1.9	1.8	0.9	2.6	1.8 (0.9)

Note: (1) numbers in the parentheses are weighted, while all others are unweighted. (2) All variables are measured at the 2005 wave unless otherwise stated.

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Table 2

Percent distribution of death from 2005 to 2008 and being healthy in 2008 by sleep quality and sleep hours.

	Women	Men	Ages 65–79	Ages 80+	Total
% Of death from 2005 to 2008					
Good sleep	42.9 (12.8)	35.6 (12.5)	11.2 (10.1)	53.3 (29.2)	39.6 (12.6)
Fair sleep	44.7 (13.2)	42.2 (15.8)	12.4 (10.9)	56.5 (31.9)	43.6 (14.3)
Poor sleep	41.1 (13.6)	47.3 (22.1)	14.7 (13.1)	59.4 (37.8)	43.3 (16.8)
Slept 5 h or less per day	39.5 (13.5)	42.3 (18.2)	23.6 (12.2)	54.5 (33.3)	40.6 (15.5)
Slept 6 h per day	42.3 (14.5)	37.0 (12.6)	11.4 (10.3)	55.7 (33.9)	40.1 (13.7)
Slept 7 h per day	33.1 (11.5)	32.4 (12.7)	11.0 (10.0)	50.0 (28.1)	32.8 (12.1)
Slept 8 h per day	37.1 (11.2)	29.7 (11.4)	10.4 (9.4)	48.7 (26.0)	33.6 (11.3)
Slept 9 h per day	35.1 (9.7)	30.3 (11.2)	9.9 (8.9)	46.7 (21.8)	32.8 (10.6)
Slept 10 h or more per day	55.9 (17.2)	50.9 (21.2)	16.0 (14.2)	61.3 (37.4)	53.9 (19.2)
Mean score of cumulative health deficit index in 2008					
Good sleep	0.23 (0.14)	0.18 (0.12)	0.12 (0.18)	0.28 (0.21)	0.21 (0.13)
Fair sleep	0.26 (0.17)	0.20 (0.13)	0.15 (0.14)	0.31 (0.23)	0.24 (0.15)
Poor sleep	0.25 (0.17)	0.22 (0.16)	0.16 (0.16)	0.32 (0.27)	0.24 (0.17)
Slept 5 h or less per day	0.25 (0.18)	0.20 (0.14)	0.16 (0.15)	0.30 (0.26)	0.23 (0.16)
Slept 6 h per day	0.23 (0.16)	0.18 (0.12)	0.14 (0.13)	0.29 (0.23)	0.21 (0.14)
Slept 7 h per day	0.21 (0.14)	0.16 (0.11)	0.14 (0.12)	0.27 (0.19)	0.19 (0.13)
Slept 8 h per day	0.21 (0.14)	0.17 (0.18)	0.12 (0.12)	0.27 (0.20)	0.19 (0.13)
Slept 9 h per day	0.23 (0.15)	0.15 (0.10)	0.12 (0.11)	0.26 (0.20)	0.19 (0.12)
Slept 10 h or more per day	0.30 (0.17)	0.23 (0.14)	0.15 (0.14)	0.32 (0.26)	0.27 (0.16)

Note: numbers in the parentheses are weighted, while others are unweighted; Cumulative health deficit index ranges 0 ~ 1.

Table 3

Relative hazards of subsequent mortality by sleep quality and duration, CLHLS, 2005–2008.

	Sleep quality		Sleep hours (8 h is the reference category)				
	Poor vs. good	**Fair vs. good**	**≤5**	**6**	**7**	**9**	**≥10**
Total							
Model I	1.26*** (1.15,1.38)	1.10 ** (1.04, 1.18)	1.19** (1.08, 132)	1.18** (1.07, 1.30)	1.03 (0.93, 1.14)	0.93 (0.82, 1.06)	1.22*** (1.13, 1.32)
Model II	1.22*** (1.12, 1.34)	1.08* (1.01, 1.15)	1.17** (1.06, 1.29)	1.17** (1.06, 1.28)	1.03 (0.93, 1.14)	0.94 (0.82, 1.06)	1.22*** (1.12, 1.32)
Model III	0.91 (0.83, 1.00)	0.94 (0.88, 1.01)	0.97 (0.88, 1.08)	1.05 (0.95, 1.16)	1, 00 (0.90, 1.11)	0.95 (0.83, 1.07)	1.09* (1.00, 1.18)
Women							
Model I	1.12 (0.99, 1.25)	1.06 (0.98, 1.16)	1.03 (0.90, 1.17)	1.14* (1.01, 1.29)	0.91 (0.79, 1.05)	0.85 (0.72, 1.01)	1.12* (1.02, 1.25)
Model II	1.09 (0.97, 1.23)	1.05 (0.96, 1.14)	1.01 (0.89, 1.16)	1.13 (0.99, 1.28)	0.92 (0.80, 1.06)	0.84 (0.72, 1.01)	1.12 (1.01, 1.24)
Model III	0.81** (0.71, 0.91)	0.93 (0.85, 1.01)	0.85* (0.75, 0.98)	1.02 (0.90, 1.15)	0.88 (0.76, 1.01)	0.86 (0.72, 1.02)	1.00 (0.90, 1.11)
Men							
Model I	1.55*** (1.33, 1.79)	1.17** (1.06, 1.30)	1.47*** (1.26, 1.71)	1.21* (1.04, 1.41)	1.20* (1.02, 1.40)	1.05 (0.87, 1.28)	1.36*** (1.20, 1.54)
Model II	1.48*** (1.27, 1.71)	1.12* (1.01, 1.25)	1.43*** (1.22, 1.67)	1.19* (1.02, 1.39)	1.19* (1.01, 1.39)	1.06 (0.88, 1.30)	1.35*** (1.19, 1.53)
Model III	1.11 (0.95, 1.30)	0.96 (0.86, 1.07)	1.17* (1.01, 1.38)	1.06 (0.91, 1.25)	1.17 (0.99, 1.37)	1.08 (0.89, 1.31)	1.22** (1.08, 1.38)
Ages 65–79							
Model I	1.37* (1.05, 1.79)	1.09 (0.88, 1.36)	1.32 (0.98, 1.77)	1.08 (0.81, 1.45)	1.07 (0.80, 1.42)	0.92 (0.63, 1.34)	1.46** (1.11, 1.91)
Model II	1.30 (0.99, 1.70)	1.07 (0.86, 1.33)	1.27 (0.95, 1.71)	1.06 (0.79, 1.42)	1.05 (0.79, 1.39)	0.93 (0.63, 1.36)	1.43* (1.09, 1.89)
Model III	0.91 (0.69, 1.20)	0.89 (0.70, 1.12)	1.00 (0.74, 1.35)	0.96 (0.72, 1.29)	1.00 (0.75, 1.34)	0.96 (0.66, 1.41)	1.17 (0.88, 1.54)
Ages 80+							
Model I	1.25*** (1.14, 1.38)	1.11*** (1.03, 1.18)	1.18** (1.06, 1.31)	1.19** (1.08, 1.32)	1.03 (0.92, 1.15)	0.94 (0.82, 1.08)	1.21*** (1.12, 1.32)
Model II	1.22*** (1.10, 1.34)	1.08* (1.01, 1.15)	1.16** (1.04, 1.29)	1.18** (1.07, 1.31)	1.03 (0.92, 1.16)	0.94 (0.82, 1.08)	1.21*** (1.11, 1.31)
Model III	0.91 (0.82, 1.00)	0.95 (0.88, 1.02)	0.97 (0.87, 1.08)	1.06 (0.95, 1.18)	1.00 (0.89, 1.12)	0.95 (0.83, 1.09)	1.08 (0.99, 1.18)

Note: Numbers in the parentheses are 95% confidence intervals; Model I controls for demographic variables (age, ethnicity, urban–rural residence, and geographic region); Model II further controls for SES, family/social support, and health practices. Model III additionally adjusts health condition (i.e., cumulative health deficit index) in 2005; relative hazards for all covariates are not presented due to space limitations, but are available upon request from authors.

* $p < 0.05$.

** $p < 0.01$.

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*** $p < 0.001$.

Table 4

Odds ratios of being in a subsequent healthy condition by sleep quality and sleeping duration, CLHLS 2005–2008.

	Sleep quality		Sleep hours (8 h is the reference category)				
	Poor vs. good	**Fair vs. good**	**≤5**	**6**	**7**	**9**	**≥10**
Total							
Model I	0.63*** (0.51, 0.77)	0.72*** (0.63, 0.83)	0.66*** (0.54, 0.80)	0.93 (0.78, 1.12)	0.96 (0.81, 1.14)	0.99 (0.80, 1.23)	0.78** (0.66, 0.93)
Model II	0.67*** (0.55, 0.82)	0.75*** (0.65, 0.86)	0.69*** (0.56, 0.84)	0.96 (0.80, 1.14)	0.98 (0.83, 1.16)	0.99 (0.79, 1.23)	0.79** (0.66, 0.94)
Model III	0.98 (0.80, 1.22)	0.91 (0.79, 1.06)	0.91 (0.74, 1.12)	1.07 (0.89, 1.29)	1.02 (0.86, 1.21)	0.99 (0.79, 1.23)	0.90 (0.75, 1.07)
Women							
Model I	0.82 (0.64, 1.06)	0.79* (0.65, 0.97)	0.67** (0.51, 0.88)	0.84 (0.65, 1.09)	1.01 (0.78, 1.29)	0.70* (0.49, 0.99)	0.68** (0.52, 0.89)
Model II	0.86 (0.67, 1.11)	0.82 (0.67, 1.00)	0.70* (0.53, 0.92)	0.87 (0.67, 1.13)	1.04 (0.81, 1.35)	0.70* (0.49, 0.99)	0.69* (0.53, 0.91)
Model III	1.26 (0.97, 1.64)	1.00 (0.82, 1.23)	0.94 (0.70, 1.25)	1.02 (0.78, 1.32)	1.11 (0.86, 1.42)	0.74 (0.52, 1.05)	0.78 (0.60, 1.02)
Men							
Model I	0.41*** (0.29, 0.57)	0.67*** (0.55, 0.81)	0.63** (0.47, 0.83)	1.02 (0.80, 1.30)	0.91 (0.72, 1.15)	1.27 (0.96, 1.69)	0.87 (0.69, 1.10)
Model II	0.45*** (0.32, 0.63)	0.69*** (0.57, 0.84)	0.65** (0.49, 0.87)	1.05 (0.82, 1.34)	0.92 (0.73, 1.16)	1.26 (0.95, 1.68)	0.88 (0.70, 1.11)
Model III	0.65* (0.46, 0.93)	0.84 (0.68, 1.03)	0.85 (0.63, 1.15)	1.13 (0.88, 1.46)	0.94 (0.74, 1.19)	1.21 (0.91, 1.62)	1.00 (0.79, 1.27)
Ages 65–79							
Model I	0.58*** (0.46, 0.72)	0.72*** (0.61, 0.85)	0.59*** (0.47, 0.75)	0.91 (0.74, 1.13)	1.07 (0.88, 1.31)	0.96 (0.74, 1.24)	0.85 (0.68, 1.07)
Model II	0.62*** (0.49, 0.78)	0.74** (0.63, 0.88)	0.62*** (0.49, 0.79)	0.95 (0.77, 1.17)	1.09 (0.89, 1.34)	0.95 (0.73, 1.26)	0.86 (0.69, 1.07)
Model III	0.92 (0.72, 1.17)	0.90 (0.75, 1.07)	0.81 (0.63, 1.04)	1.03 (0.83, 1.28)	1.13 (0.92, 1.40)	0.93 (0.72, 1.22)	0.96 (0.76, 1.21)
Ages 80+							
Model I	0.77 (0.53, 1.11)	0.72** (0.56, 0.92)	0.82 (0.58, 1.15)	0.97 (0.70, 1.32)	0.69* (0.59, 0.98)	1.08 (0.74, 1.57)	0.70* (0.52, 0.93)
Model II	0.82 (0.57, 1.19)	0.74* (0.58, 0.96)	0.84 (0.59, 1.18)	0.98 (0.72, 1.35)	0.70* (0.49, 0.99)	1.09 (0.75, 1.59)	0.70* (0.53, 0.94)
Model III	1.23 (0.84, 1.82)	0.94 (0.73, 1.22)	1.19 (0.83, 1.70)	1.18 (0.86, 1.63)	0.73 (0.52, 1.05)	1.14 (0.78, 1.67)	0.82 (0.61, 1.10)

Note: (1) Numbers in the parentheses are 95% confidence intervals. (2) Health condition in 2008 is defined by the lowest quartile of DI. (3) Model I controls for demographic variables (age, ethnicity, urban–rural residence, and geographic region). Model II further controls for SES, family/social support, and health practices. Model III additionally adjusts for health condition in 2005. (4) Odds ratios for all covariates are not presented due to space limitations, but are available upon request from authors. (5).

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.