Does More Sleep Time Improve Memory? Evidence for the Middle-Aged and Elderly

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Does More Sleep Time Improve Memory? Evidence for the Middle-Aged and Elderly

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ABSTRACT

Background: The world population is aging rapidly. However, no study exists that examines specifically the effect of sleep time on memory among the middle-aged and elderly. Purpose: This paper examines the effect of sleep time on memory for the middle-aged and elderly. Methods: Data from the China Health and Retirement Longitudinal Study (CHARLS) were analyzed using fixed-effects models for panel data. The final sample used for this study included 4,330 middle-aged and elderly adults, of which about 50.4% were male. Results: The effect of sleep time on memory is heterogeneous across gender. One more hour of sleep time per night was estimated to increase the probability of “good memory” by roughly 0.2% (p > .1) for men and 1.6% (p < .01) for women. The odds ratios of “good memory” for men and women were estimated to be around 1.05 (p > .1) and 1.6 (p < .01), respectively. Discussion: This study suggests that efforts aimed at improving sleep time can bring significant memory-related benefit to middle-aged and elderly women. Translation to Health Education Practice: Health care providers and health educators should play a role in raising middle-aged and elderly women’s general awareness of the memory-related benefit of sleep.

Background

Sleep is an important lifestyle factor that affects health. It has been established in the literature that optimizing sleep duration and quality can be an intervention to improve glucose control in patients with type 2 diabetes. Sleep is shown to affect energy balance, and more sleep is recommended to prevent obesity. While depression affects sleep, sleep restoration is associated with decreased severity of depression. Given the role of sleep in a person’s daily life and the fact that the potential health benefits of sleep have not been fully explored yet, it is no wonder that sleep has also attracted attention and received interest from mental health researchers.

As an important part of mental health, memory reflects brain functions, influences human behaviors, and impacts quality of life. After all, intelligence is essentially a memory-based process. Complaints of memory failure are common in clinics and hospital settings. Age-related memory impairment (AMI) or age-associated memory impairment (AAMI) is a natural process related to normal aging. However, it can result in meaningful impacts on a person’s life, which include reduced work efficiency and negative emotional experiences and self-evaluations. Admittedly, there are many factors that affect an individual’s memory. Studies have shown that sleep is important for cognitive performance and memory consolidation. Memory scholars divide memory into declarative (explicit) memory and procedural (implicit) memory. Declarative memory includes episodic memory that is related to the recollection of specific events and semantic memory that is associated with the long-term storage of ideas and concepts. Sleep not only aids the consolidation of episodic memory, but also facilitates the consolidation of semantic memory. Procedural memory refers to the unconscious memory of skills. Sleep is found to support the consolidation of procedural memory.

According to the International Population Reports released by the United States Census Bureau (see An Aging World: 2015 for details), the world population is aging rapidly. Median age is predicted to rise continuously in both developed and developing countries. China, the country with the largest population in the world, is no exception, and it is expected to experience a huge increase in the proportion of middle-aged and elderly people in the future. Provision of health...
promotion and wellness services for the middle-aged and elderly population is a common challenge facing different countries.

Studies in the literature generally focus on the effects of sleep in adolescents or the whole adult population. Only a few studies exist that target the middle-age and elderly specifically. Health education and health promotion targeting older people differ significantly from that targeting younger population. It is thus important to study the effect of sleep time for the middle-aged and elderly. Researchers have found that midlife and late-life sleep disturbances are associated with a higher dementia risk, and that sleep deprivation may be linked to risk factor for Alzheimer’s disease. However, the direct effect of sleep time on memory for the middle-aged and elderly is still unclear, which remains to be explored.

Purpose

The purpose of this study was to examine the effect of sleep time on memory for the middle-aged and elderly and identify possible gender heterogeneity. To the best of my knowledge, no study exists that examines specifically the effect of sleep time on memory among the middle-aged and elderly. More importantly, panel inference that can provide more robust results than cross-sectional studies would allow is sparse in the related literature. This paper aims to fill in the gap. Based on the empirical evidence from China, this study provides implications for health education and health care professionals. Possible reasons for the heterogeneous effect of sleep time on memory are discussed for future research to focus on.

Methods

Sampling

Data used in this study were from the China Health and Retirement Longitudinal Study (CHARLS). The goal of CHARLS was to provide high quality data that would meet the needs of scientific research on the middle-aged and elderly, when the rapid aging of Chinese population called for a national project that could provide sufficient micro-level longitudinal data for studies on aging problems. Officially started in 2011, the CHARLS sampled Chinese residents aged 45 and above randomly selected from 150 counties/districts and 450 villages/resident committees based on the multi-stage stratified probability proportional to size (PPS) sampling. The baseline households and individuals surveyed in 2011 were followed up every two years. Four waves had been conducted until 2018 (2011 wave 1, 2013 wave 2, 2014 wave 3, and 2015 wave 4). The household response rate exceeded 80% in all waves. Participants gave written informed consent before they participated in the survey in each wave.

A specially designed Computer-Assisted Personal Interviewing (CAPI) system was used to perform quality checks. More specifically, Global Positioning System (GPS) matching was used to ensure the sampled households were accurately located. Excessively missing data and short interviews were checked by a programmer in the CHARLS central headquarters when the survey was being conducted by two field interviewers, who also provided their personal observations about the interviewing process and the respondent’s attitude and comprehensive ability. Sound recording was checked to ensure survey questions were asked correctly and well. Households were called back by central office staff if technical issues existed that affected the sound recording checking.

The CHARLS was originally designed based on the Health and Retirement Study (HRS), the English Longitudinal Study of Aging (ELSA), and the Survey of Health, Aging and Retirement in Europe (SHARE). A pilot survey was conducted in 2008 in two provinces (Gansu and Zhejiang), after which the pilot data were analyzed to improve the quality of the questionnaire. In 2010, two additional formal pretests were deployed in two areas (Beijing and Langfang) and further modifications were made based on the pretests before the questionnaire was finalized and utilized in all waves.

Information collected in CHARLS ranges from socio-economic status to health conditions. With its extensive coverage and high accuracy, the CHARLS has been used by researchers to study aging, the effects of social policies and programs, and the relationships between lifestyles and health. In terms of sleep, while there are studies that examine the impacts of sleep on depression, grip strength, and chronic diseases based on the CHARLS data, the effect of sleep time on memory has not been investigated so far.

Since wave 3 (2014) of the CHARLS was a special survey of life history, it was not used in this study. The final sample used for this study consisted of 4,330 middle-aged and elderly adults observed in all three waves. About 50.4% were male, and the average age was around 63 years.

Measures and covariates

Participants were asked to report their demographic information and their memory status based on a five-point
Likert item: “excellent,” “very good,” “good,” “fair” or “poor” in each wave. I created a binary outcome indicator that equaled 1 if memory status was reported to be “excellent,” “very good,” or “good,” and 0 otherwise. The binary outcome indicator enabled the probability of “good memory” to be estimated based on the fixed-effects models. Since the reported memory status was the overall memory status, the outcome variable measured both declarative memory and procedural memory. Participants also reported their average sleep time per night during the past month. Sleep time was defined as the amount of time they actually slept, not the total time spent in bed per night.

Figure 1 shows the relationship between memory status and sleep time by waves. Sleep time seems to be positively correlated with memory status.

The covariates in this study included age, gender, marital status, number of grandchildren, living distance from children, and whether father/mother was still living. Normal aging is associated with a decline in various memory abilities, and its effect was captured by the inclusion of age. Expecting that there is a nonlinear relationship between normal aging and memory, I also added age squared and age cubed as control variables. Marital status was controlled for to reflect lifestyles. Since grandparenting affects cognitive health, the number of grandchildren was controlled for to capture the effect of grandparenting on memory. Living distance from children reflected the health care received from children and the empty-nest-related health effect (the effect of children’s departure on parents’ health). Whether father/mother was still living captured the effect of caring for aging parents on emotional distress and mental health. Because an individual’s memory status is affected by his or her overall health, own overall health was controlled for in the robustness check step. Summary statistics are displayed in Table 1.

Econometric analysis

To estimate the effect of sleep time on memory for the middle-aged and elderly, I first applied the following baseline model to the data:

$$Y_{it} = \beta_0 + \beta_1 S_{it} + \mathbf{X}_i \beta_2 + \alpha_i + \mu_t + \epsilon_{it} \quad (1)$$

where $Y_{it}$ is the binary indicator for memory status; $S_{it}$ is the average hours of reported sleep time per night during the past month, i.e., the average quality sleep time that a participant got per night; $\mathbf{X}_i$ contains the aforementioned control variables; $\alpha_i$ is the individual-fixed effects; $\mu_t$ is the time-fixed effects; and $\epsilon_{it}$ is the

Figure 1. Memory status vs. sleep time by waves (men and women combined). Notes: “1” indicates “good memory” (“excellent,” “very good,” or “good”) and “0” indicates the opposite (“fair” or “poor”).
random error. $\beta_1$, the coefficient of $S_{it}$, is the measure of the effect of sleep time on memory.

Individual-fixed effects controlled for omitted variables that were constant over time but varied across individuals (e.g., individual genetic characteristics), and time-fixed effects controlled for omitted variables that were constant across individuals but varied over time (e.g., improvements of medical technologies and medical services). It is possible that some omitted variables might vary both across individuals and over time (e.g., individual memory loss associated with normal aging and cardiovascular risk factors). Following the method commonly used in the literature, I added $y_i \times t$ in the baseline model to capture the long-term linear trends in memory status that might vary across individuals. Equation (2) is the extended model with individual-specific time trends:

$$Y_{it} = \beta_0 + \beta_1 S_{it} + X_{it} \beta_2 + \alpha_i + \mu_t + y_i \times t + \varepsilon_{it} \quad (2)$$

Since sleep time might have a non-linear relationship with memory, I also estimated the fixed-effects logit models with and without individual-specific time trends. STATA software (version 15) was used to conduct all the analyses. It is worth noting that statistically speaking, although the fixed-effects logit models use only within-individual differences, they are less vulnerable to omitted variable bias. Odds-ratios are more informative than marginal effects estimated from the fixed-effects logit models. 

### Results

Table 2 shows the estimated effect of sleep time on memory for the middle-aged and elderly (men and women combined). Adding individual-specific time trends did not significantly change the magnitudes of $\beta_1$, the estimated effect of sleep time on memory. One more hour of sleep time per night was estimated to increase the probability of “good memory” by roughly 1% for the middle-aged and elderly. The results from the fixed-effects logit models are listed in column (3) and column (4) of Table 2. The estimated coefficients of sleep time from the baseline and extended fixed-effects logit models were positive and significantly different from zero, indicating that sleep time per night had a significant positive effect on memory. The estimated odds ratios were significantly greater than 1 ($p < .01$), suggesting that one more hour of sleep time per day increased the odds of having a “good memory.” More sleep time per night was shown to help the middle-aged and elderly achieve a “good memory.”

An individual’s sleep time per night is affected by his or her overall health (e.g., whether the individual has mental illness or depression), and one’s overall health affects an individual’s memory. Individual-fixed effects, time-fixed effects, and individual-specific time trends

### Table 1. Summary statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory status</td>
<td>0.164</td>
<td>0.370</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sleep time (in hours)</td>
<td>6.188</td>
<td>1.957</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Age</td>
<td>62.604</td>
<td>9.667</td>
<td>45</td>
<td>101</td>
</tr>
<tr>
<td>Gender (1 = male; 0 = female)</td>
<td>0.504</td>
<td>0.500</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Marital status</td>
<td>0.681</td>
<td>0.466</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of grandchildren</td>
<td>3.864</td>
<td>3.641</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Living distance from children (in kilometers)</td>
<td>36.413</td>
<td>277.022</td>
<td>0</td>
<td>10199</td>
</tr>
<tr>
<td>Father still living (1 = yes; 0 = no)</td>
<td>0.100</td>
<td>0.300</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Mother still living (1 = yes; 0 = no)</td>
<td>0.190</td>
<td>0.392</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Overall health</td>
<td>0.224</td>
<td>0.417</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: Marital status = 1 if married and/or living with a partner; marital status = 0 if otherwise. If the participant had more than one child, the average living distance from all children was used. Overall health = 1 if overall health was reported to be “excellent,” “very good,” or “good”; overall health = 0 if overall health was reported to be “fair” or “poor.”

### Table 2. The effect of sleep time on memory.

<table>
<thead>
<tr>
<th>Estimate</th>
<th>(1) Fixed-effects linear model</th>
<th>(2) Fixed-effects linear model</th>
<th>(3) Fixed-effects logit model</th>
<th>(4) Fixed-effects logit model</th>
<th>(5) Fixed-effects logit model (Robustness test)</th>
<th>(6) Fixed-effects logit model (Robustness test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of sleep time</td>
<td>0.011***</td>
<td>0.010**</td>
<td>0.122***</td>
<td>0.300***</td>
<td>0.009***</td>
<td>0.291***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.005)</td>
<td>(0.007)</td>
<td>(0.080)</td>
<td>(0.005)</td>
<td>(0.081)</td>
</tr>
<tr>
<td>Coefficient of overall health</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.120***</td>
<td>1.080***</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>(0.022)</td>
<td>(0.297)</td>
</tr>
<tr>
<td>Individual fixed effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Individual-specific time trends</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Odds ratio</td>
<td>–</td>
<td>–</td>
<td>1.130***</td>
<td>1.350***</td>
<td>–</td>
<td>1.337***</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>(0.030)</td>
<td>(0.108)</td>
<td>–</td>
<td>(0.108)</td>
</tr>
</tbody>
</table>

Notes: Figures in parentheses are cluster-robust standard errors. Y = Yes; N = No.

** Significant at $p < .05$ level; ***Significant at $p < .01$ level.
are supposed to solve the omitted variable (OV) bias. To test the robustness of the results from the fixed-effects linear models and logit models, I added individual overall health to the regression models with individual-specific time trends.

Column (5) and column (6) of Table 2 contain the estimated effect of sleep time on memory after individual overall health was controlled for. Individual overall health positively and significantly affected an individual’s memory status ($p < .01$). However, adding overall health, a factor that significantly affects memory status, did not significantly change the estimated effect of sleep time on memory. The robustness check further confirmed the validity of the results in this study. The OV bias was resolved by adding individual-fixed effects, time-fixed effects, and individual-specific time trends to the models, and the robust effect of sleep time on memory was thus identified.

It is possible that the effect of sleep time on memory is heterogeneous across gender. Even though gender was controlled for in the analyses based on the pooled sample, the coefficient of gender could not capture the heterogenous effect of sleep time on memory because it only controlled for the gender difference in memory status not associated with sleep time. To investigate if heterogeneity exists, I applied the regression models to the subsamples that included only men and only women. The covariate “gender” was then dropped from the regression models. Results from the fixed-effects linear models and the fixed-effects logit models are listed in Tables 3 and 4 respectively.

The estimated effect of sleep time on memory for men was slightly significant (only at 10% significance level) when overall health was not controlled for.

### Table 3. The effect of sleep time on memory (fixed-effects linear).

<table>
<thead>
<tr>
<th>Coefficient of sleep time</th>
<th>0.006*</th>
<th>0.005</th>
<th>0.003</th>
<th>0.002</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.007)</td>
<td>(0.007)</td>
<td></td>
</tr>
<tr>
<td>Coefficient of overall health</td>
<td>-</td>
<td>0.128***</td>
<td>-</td>
<td>0.115***</td>
</tr>
<tr>
<td>(0.018)</td>
<td>(0.032)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall health</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Individual fixed effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Individual-specific time trends</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

### Table 4. The effect of sleep time on memory (fixed-effects logit).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of sleep time</td>
<td>0.066*</td>
<td>0.044</td>
</tr>
<tr>
<td>(0.035)</td>
<td>(0.036)</td>
<td>(0.042)</td>
</tr>
<tr>
<td>Coefficient of overall health</td>
<td>-</td>
<td>0.915***</td>
</tr>
<tr>
<td>(0.135)</td>
<td>(0.503)</td>
<td></td>
</tr>
<tr>
<td>Overall health</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Individual fixed effects</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Time fixed effects</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Individual-specific time trends</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Odds ratio</td>
<td>1.068*</td>
<td>1.045</td>
</tr>
<tr>
<td>(0.037)</td>
<td>(0.038)</td>
<td>(0.051)</td>
</tr>
</tbody>
</table>

Notes: Figures in parentheses are cluster-robust standard errors. Y = Yes; N = No.
*Significant at $p < .1$ level; ***Significant at $p < .01$ level.

However, the estimates of interest were close in magnitudes in all the baseline and extended models regardless of whether overall health was included or not, indicating that the results were consistent in this study. Since overall health was shown to be an important factor significantly affecting memory status, the estimates from the models that controlled for overall health, individual-fixed effects, time-fixed effects, and individual-specific time trends were the most precise. While sleep time only had a small positive effect on memory for middle-aged and elderly men, it had a large and significant positive effect for middle-aged and elderly women. The significant estimated effect of sleep time on memory for the middle-aged and elderly based on the pooled sample (men and women combined) was driven by the significant effect among middle-aged and elderly women. Specifically, one more hour of sleep time per night was estimated to increase the probability of “good memory” by roughly 0.2% ($p > .1$) for men and 1.6% ($p < .01$) for women (Table 3). The odds ratios of “good memory” for men and women were estimated to be around 1.05 ($p > .1$) and 1.64 ($p < .01$), respectively (Table 4). The estimated odds ratios suggested that if a middle-aged and elderly man had one more hour of sleep time per night, his odds of having a “good memory” would only change slightly. However, if a middle-aged and elderly woman had one more hour of sleep time per night, her odds of having a “good memory” would be multiplied by roughly 1.64. Put differently, female individuals with more hours of sleep were more likely to have a “good memory”.

### Discussion

I investigated the effect of sleep time on memory for the middle-aged and elderly in this study. The panel inference enabled the omitted confounders that affected memory status to be controlled for, which enhanced the robustness of the results from this study. Both the linear models and non-linear models were applied to the data, and they yielded consistent results. One more hour
of sleep time per night was estimated to increase the probability of “good memory” by roughly 1% for the middle-aged and elderly as a whole, but the effect of sleep time on memory was found to be heterogeneous across gender. It should be emphasized that the sleep time measured in this study was the amount of time participants actually slept, not the total time spent in bed. Although sleep time only has a small positive effect for middle-aged and elderly men, it has a large and significant positive effect for middle-aged and elderly women. This conclusion is consistent with findings in the literature that gender differences exist in sleep health, and that sleeping boosts women’s brain power more.

While there is a clear need for future research to identify the exact reason(s) for the heterogenous effect of sleep time on memory, this paper provides three possible reasons for future studies.

First, since women tend to multi-task and their brains are more complex than men’s, women’s sleep need is greater. It has been shown empirically that women report longer ideal sleep duration than men. The greater need for sleep may be one possible reason for the greater effect of sleep time on memory for women.

Second, studies have found that there are gender differences in circadian rhythms and slow-wave activity (SWA), which affect the homeostatic component of cognition. The greater effect for women found in this study may also be attributable to the fact that women have different circadian regulation of sleep and a greater circadian modulation of cognition due to gender differences in melatonin amplitude. This explanation echoes the finding that women tend to rebound more quickly and get greater improvements when they get more restorative sleep.

Third, compared with men, women exhibit greater signal intensity changes, which are related to neuronal activities and engagement. The greater signal intensity changes possessed by women may be another possible explanation for the heterogenous effect of sleep time.

**Strengths and limitations**

One notable strength of this study is the use of panel inference based on the fixed-effects models. The fixed-effects models enabled the omitted confounders to be controlled for, which enhanced the robustness of the estimated effect of sleep time on memory. Another strength of this study is the large sample size that provided enough statistical power to justify the results.

This study has several limitations. First, the analyses were conducted based on self-reported memory status and self-reported average hours of sleep time per night during the past month. Using clinical data would possibly strengthen the validity of the results. However, since this is the first study to provide evidence of the effect of sleep time on memory for the middle-aged and elderly and the estimates from the baseline and extended models (both linear and nonlinear) were consistent, it lays foundation for future studies that rely on clinical data. Second, the results from this study do not indicate whether sleep time has a larger effect on declarative memory or procedural memory. Even so, this study provides important policy implications for health educators. After all, an individual’s life is affected by his or her overall memory status, which includes both declarative memory and procedural memory. Third, this study does not identify which stage of the night sleep is the most crucial for memory improvement, which is another topic for future studies to investigate.

**Translation to Health Education Practice**

The effect of sleep time on memory was found to be heterogeneous across gender for the middle-aged and elderly. This study suggests that efforts aimed at improving sleep time among the middle-aged and elderly, such as community noise control during nighttime and provision of facilities and amenities that help improve sleep hygiene, can lead to improvement in memory for middle-aged and elderly women, although the effect can be insignificant for middle-aged and elderly men. Social supports to improve sleep hygiene that target middle-aged and elderly women should be advocated by health care providers and health educators. At the same time, health care providers and health educators should play a role in raising middle-aged and elderly women’s general awareness of the memory-related benefit of sleep and discouraging bad sleep habits that affect sleep time. Encouraging middle-aged and elderly women to form a habit of tracking sleep time every day can be a good way of promoting self-management that helps improve memory. Finally, health care providers and health educators should be aware that although taking medications helps reduce the symptoms of some chronic diseases, if medications negatively affect sleep time, sleep time may take a heavier toll on middle-aged and elderly women’s memory.

**Note**

1. The odds of “good memory” were defined as

   \[
   \frac{\text{Probability (good memory)}}{1 - \text{Probability (good memory)}}
   \]

   and the corresponding odds ratio was equal to
Odds of good memory (if quality sleep time per night increases by one hour)  
Odds of good memory (if quality sleep time per night is unchanged)  

Data availability

The CHARLS data are publicly available at http://charls.pku.edu.cn/en.

Disclosure statement

No potential conflict of interest was reported by the author.

Ethical approval

The Lewis University Institutional Review Board (IRB) approved this study.

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