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# Gender-specific associations between sleep quality, sleep duration and cognitive functioning among older Indians: findings from WHO-SAGE study

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**Abstract**

**Background** Sleep is an essential component of human health and well-being, playing a crucial role in several cognitive processes, including attention, memory, and executive function. In this study, we aimed to examine the association between sleep quality, sleep duration and cognitive functioning among older men and women in India.

**Methods** Data come from the World Health Organization's Study on global AGEing and adult health (WHO-SAGE), India wave-2, which was conducted in 2015 in six selected states of India, representing different country regions. The sample included 6,396 older adults aged 50 years and above. We used multivariable linear regression models to examine the associations between sleep quality, sleep duration and cognitive function, separately among older men and women.

**Results** Older men and women with poor sleep and short duration sleep had lower mean scores of cognition than their peers with good sleep and age-appropriate sleep duration. Poor sleep (aCoef: -5.09, CI: -8.66, -1.51) and short duration sleep (aCoef: -5.43, CI: -7.77, -3.10) were negatively associated with cognitive functioning among older men and the associations remained significant among older men with poor sleep (aCoef: -2.39, CI: -3.78, -1.00) and short duration sleep (aCoef: -4.39, CI: -6.46, -2.31) after adjusting for a large number of socio-demographic, health and behavioral factors. Similarly, poor sleep (aCoef: -3.15, CI: -5.79, -0.52) and short duration sleep (aCoef: -2.72, CI: -4.64, -0.81) were associated with cognitive functioning among older women, however, the associations were insignificant when the potential confounders were adjusted.

**Conclusions** This study provides evidence for the significant association between sleep health and cognitive functioning in older Indian adults, especially older men, with poor sleep quality and insufficient sleep duration being detrimental to their cognitive health. Healthcare providers should routinely screen for sleep quality and age-appropriate sleep duration in their older adult patients and consider sex/gender-tailored sleep interventions as part of cognitive health management strategies.

**Keywords** Sleep quality, Sleep duration, Cognition, Gender, Older adults

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## Background

Sleep is an essential component of human health and well-being, playing a crucial role in several cognitive processes, including attention, memory, and executive function. Changes in sleep patterns, such as decreased sleep quality and altered sleep duration, are common as people age (Pace-Schott and Spencer 2011). These alterations have been linked to cognitive decline and an increased risk of neurodegenerative diseases in older adults. Sleep quality refers to the subjective experience of sleep, which includes factors such as sleep latency, sleep efficacy, and the presence of sleep disturbances (Krystal and Edinger 2008). Numerous studies have demonstrated a strong correlation between poor sleep quality and cognitive impairment in older individuals (Keage et al. 2012; Behrens et al. 2023; Zhang et al. 2023; Miyata et al. 2013).

Inadequate sleep quality has also been associated with an increased risk of mild cognitive impairment (MCI) and dementia, including Alzheimer's disease (Rothman and Mattson 2012). Cognitive impairment is further exacerbated by sleep disorders such as sleep apnea. (Findley et al. 1986; Gagnon et al. 2014; Vanek et al. 2020). Further, the duration of sleep that is the total quantity of time an individual spends asleep also plays a role in affecting cognition (Fortier-Brochu et al. 2012). Individual sleep requirements may vary, but most adults require seven to nine hours of sleep per night for optimal cognitive function (Hirshkowitz et al. 2015). However, due to age-related changes in circadian rhythms, medical conditions, and medication use, senior adults frequently experience shorter sleep durations (Bombois et al. 2010; Mattis and Sehgal 2016). Insufficient sleep duration has been linked to deficits in cognitive domains such as consolidation of memories, attention, and executive function (Cohen-Zion et al. 2004).

Sleep is necessary for memory consolidation, the process by which newly acquired information is transformed into stable memories. Adequate sleep, specifically profound sleep or slow-wave sleep, facilitates the consolidation of memories and improves cognitive performance (Van Cauter et al. 2000; Nebes et al. 2009). Reduced sleep duration and quality impede memory retrieval and cognitive performance. Maintaining cognitive health and wellbeing in older individuals requires optimal sleep quality and duration. A meta-analysis of 45 studies on sleep quality and duration in low and middle income countries (LMICs) suggests that though sleep health parameters in LMICs are similar to those in high income countries, there is huge variability potentially due to specific sociocultural and demographic settings (Simonelli et al. 2018). Other studies also found that individuals in LMICs with sufficient sleep exhibited higher cognitive scores and those with sleep problems reported higher cognitive complaints (Gildner et al. 2014; Smith et al. 2022).

### The role of gender in sleep and cognition

Understanding the complex connection between sleep and cognition is essential for promoting healthy aging. In older individuals, sleep quality, sleep duration, and cognitive function are intricately linked. However, it is important to consider how gender may moderate this relationship. By examining the influence of gender, we can gain a deeper understanding of how specific factors interact and impact cognitive health in different populations. Research indicates that sleep patterns vary by gender (Quan et al. 2016; Rani et al. 2022). Insomnia and sleep disturbances are more prevalent among women than among men, resulting in poorer quality of sleep (Guidozzi 2015). This disparity in sleep quality between men and women may contribute to differences in cognitive performance.

Typically, older women report shorter sleep duration than older men (Rani et al. 2022). Cognitive impairments have been associated with sleep deprivation resulting from insufficient sleep duration (Lo et al. 2016). Besides, gender differences in sleep duration may contribute to cognitive function differences among older adults. In multiple ways, gender may moderate the relationship between sleep quality, sleep duration, and cognition. Importantly, hormonal fluctuations in women, such as those that occur during menopause, can affect the quality of sleep and cognitive function (Eichling and Sahni 2005). Changes in estrogen levels have been associated with sleep disorders and cognitive decline (Guidozzi 2013). These hormonal influences may partially explain why women experience poorer sleep quality and cognitive impairments than men. Secondly, gender roles and social expectations may affect sleep patterns and cognitive performance. Multiple duties and responsibilities, such as caregiving and housework, are frequently borne by women, which can result in elevated levels of stress and sleep disturbances (Cha and Eun 2014).

Additionally, cultural norms may influence men and women's sleeping habits differently (Maume et al. 2010). These factors can contribute to variations in sleep quality and duration, which in turn impact cognitive function in older individuals. Also, presence of other health conditions may impact sleep (Muhammad et al. 2023). Understanding the role of gender as a moderator in the association between sleep quality, sleep duration, and cognition has significant implications for healthcare interventions. Adapting sleep interventions to the gender-specific requirements of older adults may improve sleep quality and cognitive function. Thus, it is necessary to examine the complex gender-specific relationship between sleep quality, sleep duration, and cognition in older adults in India, emphasizing the role of various factors that may influence and affect optimal sleep patterns for healthy aging. Therefore, in this study, we aimed to examine the association between sleep quality, sleep duration and cognitive functioning among older men and women in India. We also examined the role of several socio-demographic and health-related variables in these associations (Fig. 1).

## Methods

### Data

Data come from the World Health Organization's Study on global AGEing and adult health (WHO-SAGE), India wave-2, which was conducted in 2015 in six selected states of India, representing different country regions: Assam (Northeast), Karnataka (South), Maharashtra (West), Rajasthan (North), Uttar Pradesh (Central) and West Bengal (East), covering a broadly illustrative aggregate sample of 9,116 respondents aged 18 years and above. SAGE wave-2 India was a follow-up study of SAGE wave-1 and covered the same states with the same primary sampling units (PSU) and the sample households which were covered in the WHO-World Health Survey (WHS), 2003. From all the states in India, a systematic random sample selection procedure was followed to select the states in WHS. Two-stage sampling in rural areas was used where the villages were the PSUs and households as secondary stage unit (SSU). Three-stage sampling in urban areas with the selection of wards, census enumeration blocks, and households in a specific order was followed. The number of households selected was in proportion to the respective state population and was distributed in urban and rural population. More detailed Information about weights and survey design is available at https://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/117. SAGE Wave-2 had two target populations: a large sample of persons aged 50 years and older, which is the focus of the study, and a smaller sample of persons aged 18–49 years. The survey had a response rate of 77% for the individual questionnaire (Arokiasamy et al. 2020). The number of respondents in WHO-SAGE, waive-2 included 1,998 aged 18–49 years and 7,118 older adults aged 50 and above. This study considered respondents aged 50 years and above. After removing the sample with missing information on cognition, our analytical sample reduced to 6,396 older adults age 50 years and above.

### Measurements

#### *Outcome variable*

Cognitive functioning was assessed using variables such as verbal fluency, verbal recall, digit span forward and digit span backward. For assessing verbal recall, interviewer read out a list of ten commonly used words to the respondents and asked them to repeat again in some time. For assessing verbal fluency, respondents were asked to produce as many animal names as possible in one minute time span. Finally for assessing the digit span, which was utilized to measure working memory, interviewer read a series of digits and asked to immediately repeat them back. In the backward test, the person must repeat the numbers in reverse order. A series of number sequences was presented and the respondent was asked to reproduce the exact same sequence. Following a correct recall, longer sequences were given until failure. The

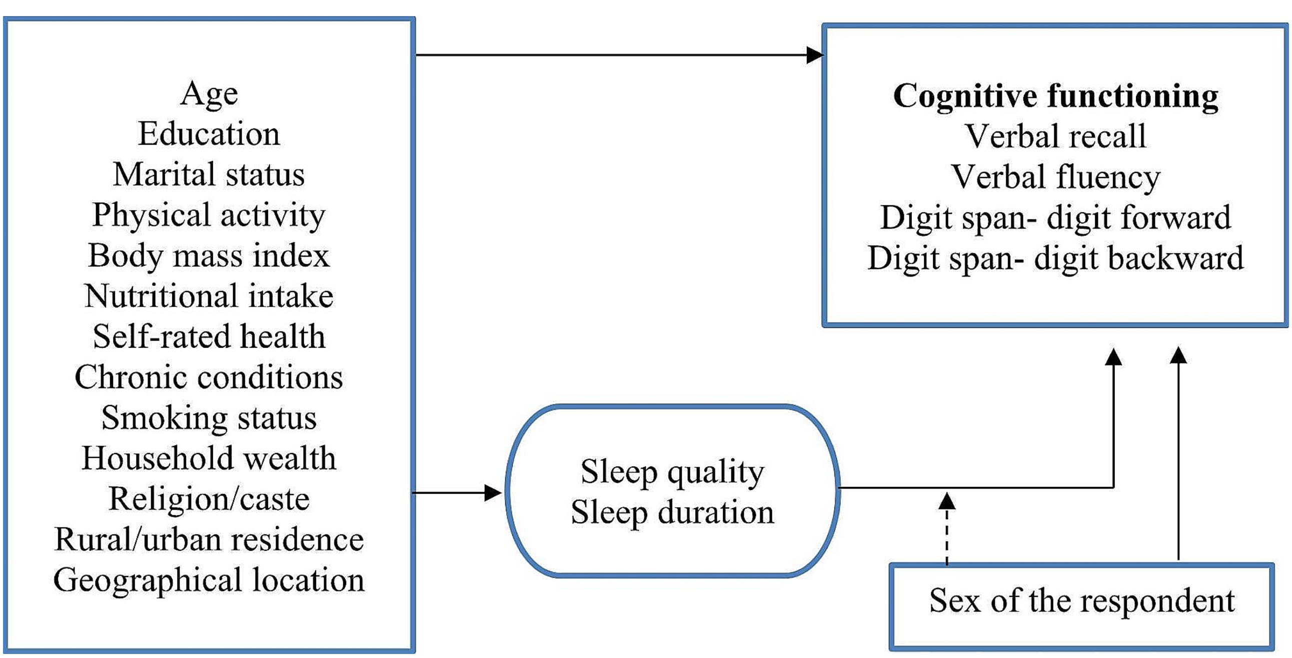


**Fig. 1** Conceptual framework

maximum score for the forward digit count was 9 with a range of 0–9; the score for the backward digit count ranged from 0 to 8 and a summary score, created by adding forward and backward counting scores, ranged from 0 to 17. The verbal fluency test measured respondents' ability to retrieve information from semantic memory. This was a one minute assessment in which respondents were asked to name as many animals as they could. The verbal fluency score was defined by the number of correctly named animals. Repeated names were not counted.

The overall cognitive score was obtained by adding scores of verbal recall, digit counting, forward and backward, and verbal fluency tests. The scores on these four tests, which were in different scales, were standardised by rescaling them to have a mean of zero and a standard deviation of one, and z-score was generated for each measures. Further, a composite cognitive score was created using a principal components analysis (PCA). Finally, the generated index was converted into a 0 (worst cognition) to 100 (best cognition) scale which facilitates easier interpretation of the data.

#### *Key explanatory variables*

Main predictor variables in this study were sleep quality and sleep duration. Sleep quality was assessed using the question, "Please rate the quality of your sleep last night. Was it very good, good, moderate, poor or very poor?" Sleep duration was assessed using the question, "How many hours did you sleep last night?" The responses in the format of minutes were converted into hours and the duration was classified as per the total number of hours the respondent slept in the last night. Less than seven hours was classified as short duration sleep, 7–8 h was considered as normal sleep and 9 and more hours was considered as long duration sleep among older adults in this study, as recommended by the National Sleep Foundation (Hirshkowitz et al. 2015).

#### *Covariates*

Health and behavioral factors included nutritional intake, assessed by the total number of fruit and vegetable servings per day (recoded as no for four or less servings, and yes for more than 4 times per day) (Patel et al. 2019), body mass index (measured based on height and weight, and classified as per WHO criteria; less than 18.5 kg/m2 as underweight, 18.5–24.9 kg/m2 as normal, 25.0–29.9 kg/m2 as overweight, and ≥30.0 kg/m2 as obese), and physical activity (vigorous, moderate, light and no activity). For physical activity, the questions assessed the duration of activity (minutes and/or hours) on a typical day. The duration of activity included: (i) activities at the workplace, (ii) activities done as part of travel to and from places, and (iii) leisure time or recreational physical activities. We followed the WHO global guidelines on physical activity for adult health, categorized as vigorous activity, moderate activity and light activity and physical inactivity (Organization 2020). Vigorous activity includes individuals spending at least 75 min on a vigorously intensive activity on a typical day. Moderate activity includes individuals spending time at least 150 min on moderately intensive activity on a typical day. Light activity include any activity that does not fall in the above two categories.

Self-rated health was assessed using a single overall self-rated general health question used in SAGE: "In general, how would you rate your health today?" with a five-point response scale from very good to very bad. Number of chronic conditions was classified into none, single, two and three and more. Chronic conditions in this study included having diagnosed with any of the following conditions; hypertension, diabetes, stroke, arthritis, angina, asthma and chronic lung disease. The question format used was, "Have you ever been diagnosed with the condition?" for each health condition. Smoking status was recoded into never smoked, currently not smoking and currently smoking.

Socio-demographic variables in this study included age (grouped as 50–59, 60–69, 70–79, 80+years), sex (male and female), educational level (no education, less than primary, primary, secondary and higher), and current marital status (married, widowed and others which include never married/ separated/ divorced). Household related variables included household wealth index (computed based on a detailed list of items of household assets and was available on five quintiles and lowest represents the quintile with the poorest households and highest represents the quintile with the richest households), religious groups (Hindus, Muslims and others), social groups (scheduled castes and scheduled tribes [both are socioeconomically most disadvantaged] and others), place of residence (urban and rural), and states (Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal).

### Statistical analysis

We conducted the descriptive statistics to present the characteristics of the study sample. Further, we presented the mean scores of cognitive functioning among older adults by explanatory variables, including sleep quality and duration, along with 95% confidence intervals (CIs). Finally, we used multivariable linear regression models to examine the association between sleep quality, duration and cognitive function. We employed four models to examine the unadjusted and adjusted linear regression estimates of cognitive functioning by sleep quality and duration. First model provides the unadjusted estimates, second model is adjusted for the selected socio-demographic variables, third model is additionally adjusted for the selected household-related variables and fourth or final model is a full model adjusted for all the selected covariates including the health and behavioral factors.

Survey weights were applied to account for the complex survey design and to provide the estimates at population level. Regression diagnostics such as variance inflation factor (VIF) for multicollinearity (Table S1) and tests for linearity and normality of residuals (Figures S1 & S2) were carried out and found no violation of basis assumptions of regression (see Supplemental material). We report the results in the form of weighted means, and unadjusted and adjusted coefficients (aCoef) with 95% CIs. All the analyses were carried out in Stata version 15.1 (StataCorp 2017).

## Results

Table 1 presents the sample characteristics. Around 5% of the sample age 80+years, 47.98% of the participants had no formal education and a total of 23.39% of the participants were widowed in this study. Around 19% of older participants reported 5+intake of fruit and vegetables per day, 27.3% were underweight, 15.54% were overweight and 3.61% were obese in this study. A large proportion of the sample (43.98%) reported that they were engaged in none of the physical activities whereas, 21.08% of males and 10.38% of females reported engaging in vigorous physical activity. Around 18% of the participants had a bad or very bad self-rated health whereas, around 42% of the participants had at least one chronic condition.

Table 2 provides the mean scores of cognitive functioning (on a scale of 0-100) among older adults by selected background variables. Older men and women with a poor sleep and short sleep duration had lower mean scores of cognition than their peers with good sleep and age-appropriate sleep duration. Older men consistently exhibited higher mean scores for cognitive functioning across all age groups. For instance, men in the 50–59 years age group had a mean score of 62.83 (CI: 61.55, 64.11), while women had a mean score of 56.41 (CI: 55.41, 57.42). This is consistent across all age categories. Men had higher mean scores across different education levels as compared to women except in the high school level, where men scored 62.53 (CI: 61.24, 63.83) compared to women's score of 67.62 (CI: 63.71, 71.53), and college level, where men scored 67.34 (CI: 64.20, 70.47) compared to women's score of 69.86 (CI: 66.29, 73.42).

Table 3 presents the multivariable linear regression estimates of cognitive functioning among older men. Poor sleep (aCoef: -5.09, CI: -8.66, -1.51) and short sleep (aCoef: -5.43, CI: -7.77, 3.10) was negatively associated with cognitive functioning among older men. The associations remained significant among older men with poor sleep (aCoef: -2.39, CI: -3.78, -1.00) and short sleep (aCoef: -4.39, CI: -6.46, -2.31) after adjusting for a large number of socio-demographic and health-related variables. In comparison to the reference group (50–59 years), there is a decline in cognitive functioning in older men belonging to 60–69 age group (aCoef: -3.09, CI: -4.46, -1.72), 70–79 age group (aCoef: -4.49, CI: -6.30, -2.68), and 80+age group (aCoef: -9.22, CI: -12.2, -6.19). Further, there was a positive association between cognitive functioning and education across all levels, with the highest likelihood observed among those who have attended college (aCoef: 11.5, CI: 8.49, 14.4). Widowhood is linked to a notable decrease in cognitive functioning (aCoef: -2.52, CI: -4.34, -0.69), whereas no significant association was found for other marital statuses. Overweight (aCoef: 2.18, CI: 0.23, 4.12) and obesity (aCoef: 3.67, CI: 0.52, 6.81) were significantly associated with improved cognition whereas, physical inactivity was significantly associated with poor cognitive function among older men (aCoef: -1.34, CI: -2.77, -0.088). Self-rated health demonstrates a significant association with cognitive functioning, particularly in the moderate and bad health categories (aCoef: -3.93, CI: -6.98, -0.87 and aCoef: -4.44, CI: -7.83, -1.04, respectively). The cognitive functioning was much lower for older men in rural areas (aCoef: -2.24, CI: -4.03, -0.46) compared to those in urban areas. Nutritional intake, chronic conditions, smoking status, wealth quintile, religion, social group, and states did not exhibit significant associations with cognitive functioning.

Table 4 presents the multivariable linear regression estimates of cognitive functioning among older women. Poor sleep (aCoef: -3.15, CI: -5.79, -0.52) and short sleep (aCoef: -2.72, CI: -4.64, -0.81) was negatively associated with cognitive functioning among older women, however, the associations were insignificant when the potential health and behavioral confounders were adjusted. Compared to the reference group (50–59 years), cognitive functioning decreased in 60–69 age group (aCoef: -1.32, CI: -2.58, -0.065), 70–79 age group (aCoef: -4.20, CI: -5.82, -2.57) and 80+age group (aCoef: -3.34, CI: -6.89, -0.22). A positive association of cognitive functioning with all levels of education was observed, with the highest levels observed for the college-educated group (aCoef: 13.2, CI: 9.31, 17.1). Being widowed had a significant effect on declining cognitive functioning among older women (aCoef: -1.54, CI: -2.83, -0.26). Having a higher nutritional intake had a significantly positive effect on the levels of cognitive functioning (aCoef: 2.83, CI: 1.27, 4.40). Compared to being underweight, normal, overweight, and obese categories had significantly increased levels of cognitive functioning. Moderate physical activity had a significant positive effect on cognitive functioning (aCoef: 2.56, CI: 0.32, 4.81). Self-rated health, chronic conditions, smoking status, wealth quintile,

**Table 1** Sample characteristics

| Variables | Men | Women | Total |
|---|---|---|---|
| Age (in years) | | | |
| 50–59 | 1046 (35.37) | 1568 (46.07) | 2614 (40.95) |
| 60–69 | 1178 (38.87) | 1157 (34.2) | 2335 (36.43) |
| 70–79 | 609 (19.82) | 536 (15.54) | 1145 (17.59) |
| 80+ | 181 (5.94) | 121 (4.2) | 302 (5.03) |
| Level of education | | | |
| No formal education | 887 (26.48) | 2295 (67.7) | 3182 (47.98) |
| Less than primary | 480 (15.72) | 361 (10.99) | 841 (13.26) |
| Primary | 545 (17.91) | 360 (10.18) | 905 (13.88) |
| Secondary | 424 (14.83) | 189 (5.25) | 613 (9.83) |
| High school | 400 (13.96) | 98 (3.29) | 498 (8.39) |
| College | 278 (11.09) | 79 (2.59) | 357 (6.66) |
| Current marital status | | | |
| Married | 2663 (87.96) | 2122 (63.09) | 4785 (74.98) |
| Widowed | 293 (9.81) | 1211 (35.84) | 1504 (23.39) |
| Others | 58 (2.23) | 49 (1.07) | 107 (1.62) |
| Nutritional intake (> 4 times per day) | | | |
| No | 2412 (79.52) | 2798 (82.24) | 5210 (80.94) |
| Yes | 602 (20.48) | 584 (17.76) | 1186 (19.06) |
| Body mass index | | | |
| Underweight | 791 (27.17) | 856 (27.43) | 1647 (27.3) |
| Normal | 1700 (57.41) | 1705 (50) | 3405 (53.54) |
| Overweight | 377 (13.38) | 551 (17.53) | 928 (15.54) |
| Obese | 68 (2.04) | 170 (5.05) | 238 (3.61) |
| Physical activity | | | |
| Vigorous | 654 (21.08) | 374 (10.38) | 1028 (15.51) |
| Moderate | 536 (17.82) | 1079 (31.74) | 1615 (25.07) |
| Light | 534 (20.43) | 330 (11.43) | 864 (15.74) |
| None | 1278 (40.67) | 1576 (46.45) | 2854 (43.68) |
| Self-rated health | | | |
| Very good | 136 (4.45) | 102 (2.83) | 238 (3.61) |
| Good | 986 (33.73) | 988 (29.3) | 1974 (31.42) |
| Moderate | 1437 (46.33) | 1649 (48.01) | 3086 (47.21) |
| Bad | 416 (13.93) | 603 (18.46) | 1019 (16.29) |
| Very bad | 38 (1.55) | 40 (1.39) | 78 (1.47) |
| Chronic conditions | | | |
| Zero | 1698 (59.98) | 1772 (56.37) | 3470 (58.1) |
| Single | 837 (25.25) | 1019 (27.91) | 1856 (26.64) |
| Two | 319 (9.67) | 442 (11.74) | 761 (10.75) |
| Three and more | 160 (5.1) | 149 (3.98) | 309 (4.52) |
| Smoking | | | |
| Never | 1625 (48.79) | 3085 (81.83) | 4710 (66.10) |
| Currently not | 489 (14.48) | 335 (8.26) | 824 (11.22) |
| Currently smoking | 1217 (36.72) | 352 (9.91) | 1569 (22.68) |
| Wealth quintile | | | |
| Poorest | 560 (18.62) | 672 (21.1) | 1232 (19.91) |
| Poor | 543 (18.14) | 628 (18.05) | 1171 (18.09) |
| Middle | 571 (18.2) | 622 (18.2) | 1193 (18.2) |
| Rich | 606 (20.49) | 703 (21.54) | 1309 (21.04) |
| Richest | 734 (24.55) | 757 (21.12) | 1491 (22.76) |
| Religion | | | |
| Hindu | 2512 (84.5) | 2834 (84.96) | 5346 (84.74) |
| Muslim | 378 (12.3) | 415 (11.99) | 793 (12.14) |

**Table 1** (continued)

| Variables | Men | Women | Total |
|---|---|---|---|
| Others | 124 (3.2) | 133 (3.05) | 257 (3.12) |
| Social group | | | |
| Scheduled castes | 217 (5.93) | 265 (6.99) | 482 (6.48) |
| Scheduled tribes | 478 (14.4) | 571 (15.18) | 1049 (14.81) |
| Other backward classes | 1397 (49.4) | 1558 (49.71) | 2955 (49.56) |
| Others | 922 (30.26) | 988 (28.12) | 1910 (29.15) |
| Place of residence | | | |
| Urban | 580 (26.96) | 711 (27.85) | 1291 (27.42) |
| Rural | 2434 (73.04) | 2671 (72.15) | 5105 (72.58) |
| States | | | |
| Assam | 326 (5.27) | 351 (5.3) | 677 (5.29) |
| Karnataka | 274 (8.45) | 340 (9.18) | 614 (8.83) |
| Maharashtra | 514 (23.07) | 569 (21.52) | 1083 (22.26) |
| Rajasthan | 623 (12.26) | 736 (13.1) | 1359 (12.7) |
| Uttar Pradesh | 690 (32.63) | 680 (31.01) | 1370 (31.78) |
| West Bengal | 587 (18.33) | 706 (19.9) | 1293 (19.15) |
| Total | 3014 (100) | 3382 (100) | 6396 (100) |

Percentages are weighted to account for complex survey design and to account for population estimates

religion, social group, place of residence, and states did not show significant effects on cognitive functioning.

## Discussion

The findings of this study provide substantial evidence for the association between sleep and cognitive functioning in older individuals. Bivariate results suggest that both poor sleep quality and reduced sleep duration were associated with reduced cognitive performance in both men and women. These results are consistent with previous research and emphasize the importance of sleep for maintaining optimal cognitive function (Engleman et al. 2000; Saint Martin et al. 2012). Sleep disturbances can impair cognitive processes such as memory consolidation and neural repair, resulting in cognitive decline (Aly and Moscovitch 2010).

It is noteworthy that, across all age categories, men consistently demonstrated higher mean cognitive functioning scores. This suggests that men may be more resistant than women to the cognitive effects of increasing age. This finding is in line with other studies that found that older women often scored less in cognitive scores as compared to older men (Zhang 2006; Wang et al. 2020). The findings also reveal gender-specific differences in the association between sleep and cognitive functioning. Unlike older men, cognitive effects of poor sleep quality and short sleep were insignificant among older women after adjusting for health and behavioural factors. This suggests an independent association between sleep and cognition among men but not women. Additional research is required to comprehend these gender differences and their underlying mechanisms. Hormonal variations, caregiving responsibilities, and societal expectations may contribute to men's and women's distinctive sleep patterns and cognitive outcomes (Roepke and Ancoli-Israel 2010; Mallampalli and Carter 2014).

While the association between sleep and cognitive functioning is well-established, this study extends the understanding by examining the role of various background factors. Age was found to significantly moderate the relationship between sleep and cognitive functioning, with higher cognitive decline observed among women as age increased which is supported by previous research (Dzierzewski et al. 2018). This finding underscores the need for targeted interventions to support cognitive health in older women, particularly as they age. Education level also emerged as a significant factor, indicating that higher educational attainment acts as a protective factor against cognitive decline in older adults, and in women in particular, cohesive with the extensive body of literature (van Hooren et al. 2007; Tripathi et al. 2014; Muhammad et al., 2022a). Education provides individuals with cognitive reserve, enhances access to healthcare, promotes engagement in mentally stimulating activities, and encourages the adoption of healthier lifestyles. These factors collectively contribute to better cognitive functioning and may mitigate the negative impact of poor sleep on cognitive health, especially among women due to gender-specific behavior and societal roles.

Marital status demonstrated significant relationship with cognitive functioning. Specifically, widowhood was significantly associated with decreased levels of cognitive functioning, though observed in both men and women. This finding has been supported by existing research (Xu et al. 2021). The negative impact of widowhood on cognitive functioning may be attributed to factors such as

**Table 2** Weighted mean scores of cognitive functioning (on a scale of 0-100) among older adults by their background characteristics

| Variables | Men | | Women | | Total | |
|---|---|---|---|---|---|---|
| | **Mean** | **95% Confidence intervals** | **Mean** | **95% Confidence intervals** | **Mean** | **95% Confidence intervals** |
| Sleep quality | | | | | | |
| Good | 57.48 | 56.57, 58.38 | 52.18 | 51.38, 52.97 | 54.81 | 54.19, 55.43 |
| Moderate | 53.9 | 52.37, 55.43 | 50.1 | 48.95, 51.24 | 51.69 | 50.74, 52.64 |
| Poor | 52.95 | 49.59, 56.30 | 49.79 | 47.45, 52.14 | 51.42 | 49.30, 53.55 |
| Sleep duration | | | | | | |
| Normal | 57.28 | 56.06, 58.50 | 51.68 | 50.77, 52.59 | 54.38 | 53.59, 55.16 |
| Short | 51.91 | 50.01, 53.80 | 48.95 | 47.36, 50.54 | 50.34 | 49.09, 51.59 |
| Long | 57.01 | 56.05, 57.97 | 52.2 | 51.12, 53.28 | 54.5 | 53.75, 55.24 |
| Age (in years) | | | | | | |
| 50–59 | 62.83 | 61.55, 64.11 | 56.41 | 55.41, 57.42 | 59.07 | 58.23, 59.90 |
| 60–69 | 58.21 | 56.98, 59.44 | 53.28 | 52.15, 54.41 | 55.8 | 54.94, 56.65 |
| 70–79 | 55.83 | 54.05, 57.61 | 48.68 | 47.40, 49.96 | 52.53 | 51.31, 53.75 |
| 80+ | 49.6 | 46.82,52.38 | 46.43 | 43.22, 49.64 | 48.22 | 46.13, 50.31 |
| Level of education | | | | | | |
| No formal education | 51.32 | 50.33, 52.31 | 50.4 | 49.69, 51.10 | 50.64 | 50.06, 51.22 |
| Less than primary | 57.18 | 55.07, 59.28 | 56.46 | 54.33, 58.58 | 56.87 | 55.35, 58.38 |
| Primary | 59.15 | 57.62, 60.67 | 59.75 | 58.06, 61.45 | 59.38 | 58.23, 60.52 |
| Secondary | 63.97 | 61.77, 66.17 | 62.49 | 60.14, 64.83 | 63.56 | 61.82, 65.29 |
| High school | 62.53 | 61.24, 63.83 | 67.62 | 63.71, 71.53 | 63.57 | 62.20, 64.95 |
| College | 67.34 | 64.20, 70.47 | 69.86 | 66.29, 73.42 | 67.85 | 65.26, 70.44 |
| Current marital status | | | | | | |
| Married | 59.55 | 58.68, 60.41 | 55.57 | 54.74, 56.40 | 57.8 | 57.18, 58.42 |
| Widowed | 53.07 | 51.31, 54.83 | 50.44 | 49.36, 51.52 | 50.97 | 50.03, 51.90 |
| Others | 57.22 | 52.84, 61.61 | 54.61 | 49.96, 59.26 | 56.33 | 52.95, 59.71 |
| Nutritional intake (> 4 times per day) | | | | | | |
| No | 58.52 | 57.57, 59.48 | 53.06 | 52.31, 53.81 | 55.63 | 55.01, 56.25 |
| Yes | 60.17 | 58.87, 61.48 | 56.78 | 55.28, 58.28 | 58.52 | 57.52, 59.53 |
| Body mass index | | | | | | |
| Underweight | 54.55 | 53.51, 55.60 | 49.6 | 48.47, 50.74 | 51.96 | 51.16, 52.76 |
| Normal | 60.06 | 58.93, 61.19 | 54.18 | 53.31, 55.05 | 57.2 | 56.45, 57.95 |
| Overweight | 63.27 | 61.05, 65.50 | 58.3 | 56.35, 60.24 | 60.35 | 58.83, 61.87 |
| Obese | 63.46 | 59.21, 67.71 | 59.4 | 56.94, 61.86 | 60.5 | 58.38, 62.62 |
| Physical activity | | | | | | |
| Vigorous | 59.44 | 58.25, 60.64 | 52.3 | 50.14, 54.45 | 56.95 | 55.80, 58.10 |
| Moderate | 59.67 | 57.55, 61.79 | 56.1 | 54.94, 57.26 | 57.32 | 56.24, 58.39 |
| Light | 60.68 | 58.96, 62.41 | 54.07 | 51.88, 56.26 | 58.19 | 56.80, 59.57 |
| None | 57.31 | 55.94, 58.68 | 52.41 | 51.49, 53.34 | 54.6 | 53.77, 55.43 |
| Self-rated health | | | | | | |
| Very good | 66.57 | 62.16, 70.97 | 60.87 | 57.33, 64.40 | 64.23 | 61.15, 67.32 |
| Good | 61.74 | 60.16, 63.32 | 56.12 | 54.86, 57.38 | 59 | 57.94, 60.06 |
| Moderate | 57.56 | 56.62, 58.49 | 53.33 | 52.43, 54.22 | 55.31 | 54.65, 55.97 |
| Bad | 54.08 | 52.42, 55.73 | 50.47 | 49.02, 51.92 | 51.94 | 50.83, 53.05 |
| Very bad | 56.2 | 51.92, 60.48 | 45.53 | 39.37, 51.69 | 50.93 | 46.59, 55.27 |
| Chronic conditions | | | | | | |
| Zero | 59.33 | 58.19, 60.48 | 53.26 | 52.36, 54.16 | 56.26 | 55.50, 57.02 |
| Single | 58.46 | 57.27, 59.65 | 53.58 | 52.31, 54.84 | 55.79 | 54.88, 56.70 |
| Two | 58.38 | 56.39, 60.38 | 55.62 | 53.98, 57.27 | 56.81 | 55.53, 58.09 |
| Three and more | 56.23 | 52.52, 59.93 | 55.67 | 51.77, 59.57 | 55.97 | 53.29, 58.65 |
| Smoking | | | | | | |
| Never | 58.71 | 57.89, 59.53 | 54.65 | 53.83, 55.47 | 56.05 | 55.33, 56.76 |
| Currently not | 58.13 | 56.65, 59.62 | 53.37 | 51.34, 55.41 | 56.24 | 54.79, 57.68 |
| Currently smoking | 57.85 | 56.68, 59.01 | 51.59 | 49.49, 53.69 | 56.49 | 55.24, 57.74 |

**Table 2** (continued)

| Variables | Men | | Women | | Total | |
|---|---|---|---|---|---|---|
| | Mean | 95% Confidence intervals | Mean | 95% Confidence intervals | Mean | 95% Confidence intervals |
| Wealth quintile | | | | | | |
| Poorest | 53.37 | 52.08, 54.66 | 50.1 | 48.88, 51.31 | 51.56 | 50.68, 52.45 |
| Poor | 57.4 | 55.54, 59.27 | 51.07 | 49.90, 52.25 | 54.11 | 52.93, 55.29 |
| Middle | 58.43 | 56.74, 60.13 | 53.09 | 51.29, 54.88 | 55.64 | 54.37, 56.92 |
| Rich | 59.37 | 57.81, 60.92 | 54.1 | 52.75, 55.45 | 56.55 | 55.49, 57.62 |
| Richest | 64 | 62.16, 65.84 | 59.77 | 58.27, 61.26 | 61.95 | 60.73, 63.17 |
| Religion | | | | | | |
| Hindu | 59.11 | 58.22, 60.00 | 53.57 | 52.83, 54.32 | 56.21 | 55.61, 56.81 |
| Muslim | 58.22 | 56.45, 59.99 | 54.58 | 52.88, 56.28 | 56.35 | 55.12, 57.57 |
| Others | 54.81 | 50.40, 59.21 | 54.42 | 52.03, 56.81 | 54.61 | 52.13, 57.09 |
| Social group | | | | | | |
| Scheduled castes | 54.42 | 52.42, 56.41 | 51.29 | 49.65, 52.94 | 52.66 | 51.38, 53.94 |
| Scheduled tribes | 55.74 | 54.40, 57.09 | 50.43 | 49.17, 51.68 | 52.9 | 51.96, 53.84 |
| Other backward classes | 59.09 | 57.83, 60.35 | 53.85 | 52.76, 54.94 | 56.35 | 55.49, 57.20 |
| Others | 60.85 | 59.43, 62.26 | 55.88 | 54.74, 57.01 | 58.34 | 57.41, 59.28 |
| Place of residence | | | | | | |
| Urban | 63.49 | 61.23, 65.75 | 56.87 | 54.98, 58.76 | 59.98 | 58.44, 61.52 |
| Rural | 57.15 | 56.60, 57.71 | 52.51 | 51.97, 53.05 | 54.74 | 54.35, 55.14 |
| States | | | | | | |
| Assam | 55.93 | 54.74, 57.12 | 52.74 | 51.61, 53.87 | 54.26 | 53.43, 55.09 |
| Karnataka | 55.08 | 53.36, 56.80 | 54.8 | 52.95, 56.65 | 54.93 | 53.65, 56.20 |
| Maharashtra | 62.62 | 60.17, 65.06 | 54.61 | 52.53, 56.70 | 58.58 | 56.86, 60.30 |
| Rajasthan | 58.71 | 57.86, 59.57 | 52.07 | 51.24, 52.90 | 55.14 | 54.51, 55.77 |
| Uttar Pradesh | 57.97 | 56.88, 59.06 | 52.23 | 51.02, 53.43 | 55.05 | 54.21, 55.88 |
| West Bengal | 58.41 | 57.02, 59.80 | 55.94 | 54.80, 57.07 | 57.07 | 56.18, 57.96 |
| Total | 58.86 | 58.06, 59.66 | 53.72 | 53.05, 54.39 | 56.18 | 55.64, 56.72 |

social isolation, loss of support networks, and emotional stress (Förster et al. 2021). These factors may interact with poor sleep quality or shorter sleep duration, exacerbating cognitive decline in older men. On the other hand, no significant associations were found for other marital statuses, indicating that the influence of marital status on cognitive functioning may be more nuanced and multifaceted.

Nutritional intake was significantly associated with cognitive functioning in this study, and should not be overlooked as an important factor for overall health and well-being. Adequate nutrition is essential for optimal cognitive function (Selvamani and Singh 2018; Khan 2022), and it may interact with sleep patterns and quality to influence cognitive outcomes indirectly. Future research should explore the complex interplay between sleep, nutritional intake, and cognitive functioning to gain a more comprehensive understanding of their combined effects. Further, physically inactive older men had poor cognition and older women who engaged in moderate physical activity had improved cognition in this study which corresponds to previous studies (Barha et al. 2017; Castells-Sanchez et al. 2021; Sekher and Muhammad 2023). Self-rated health demonstrated a significant effect among older men but not women, particularly in the moderate and bad health categories. Older men who rated their health as moderate or bad exhibited a lower level of cognitive functioning which suggest differential effects of one's perceived health on their cognitive functioning among men and women which require further investigation. Poor sleep quality or shorter sleep duration may contribute to worse self-rated health (Frange et al. 2014; Simoes Maria et al. 2020), leading to a vicious cycle of deteriorating cognitive health. Interventions aimed at improving sleep quality and duration may have indirect benefits by enhancing overall health and well-being, thus positively impacting cognitive functioning.

Our results also revealed that place of residence played a moderating role in the association between sleep and cognitive functioning. Notably, older men residing in urban areas consistently displayed higher mean scores for cognitive functioning compared to those in rural areas which is consistent with findings from previous research (Xu et al. 2018; Srivastava and Muhammad 2022) These findings suggest that the urban environment may provide more favorable conditions for cognitive health, potentially due to better access to healthcare facilities, social engagement opportunities, and a more stimulating living environment. Further research is needed to examine the specific mechanisms underlying this association and

**Table 3** Estimates from general linear models of cognitive functioning by background variables among older men SAGE- 2015

| **Variables** | **Unadjusted coefficients (95% CI)** | **Model 1** | **Model 2** | **Model 3** |
|---|---|---|---|---|
| | | **Adjusted coefficients (95% CI)** | **Adjusted coefficients (95% CI)** | **Adjusted coeffi-cients (95% CI)** |
| Sleep quality | | | | |
| Good | Ref. | Ref. | Ref. | Ref. |
| Moderate | -3.85*** (-5.69 - -2.02) | -2.56*** (-4.11 - -1.01) | -2.82*** (-4.24 - -1.39) | -2.39*** (-3.78 - -1.00) |
| Poor | -5.09*** (-8.66 - -1.51) | -3.24* (-6.48–0.0037) | -3.75** (-6.63 - -0.87) | -2.34 (-5.41–0.74) |
| Sleep duration | | | | |
| Normal | Ref. | Ref. | Ref. | Ref. |
| Short | -5.43*** (-7.77 - -3.10) | -3.92*** (-6.11 - -1.72) | -4.35*** (-6.39 - -2.32) | -4.39*** (-6.46 - -2.31) |
| Long | 0.47 (-1.13–2.06) | -0.0016 (-1.38–1.38) | 0.14 (-1.10–1.38) | 0.10 (-1.11–1.31) |
| Age (in years) | | | | |
| 50–59 | Ref. | Ref. | Ref. | Ref. |
| 60–69 | -4.41*** (-6.11 - -2.71) | -3.97*** (-5.50 - -2.43) | -3.53*** (-4.88 - -2.17) | -3.09*** (-4.46 - -1.72) |
| 70–79 | -6.71*** (-8.81 - -4.61) | -5.16*** (-7.20 - -3.13) | -5.53*** (-7.30 - -3.76) | -4.49*** (-6.30 - -2.68) |
| 80+ | -12.7*** (-15.6 - -9.76) | -10.4*** (-13.7 - -7.04) | -10.5*** (-13.6 - -7.38) | -9.22*** (-12.2 - -6.19) |
| Level of education | | | | |
| No formal education | Ref. | Ref. | Ref. | Ref. |
| Less than primary | 5.65*** (3.43–7.88) | 5.50*** (3.26–7.74) | 4.59*** (2.68–6.49) | 4.50*** (2.56–6.45) |
| Primary | 7.56*** (5.82–9.30) | 6.88*** (5.10–8.65) | 5.78*** (4.15–7.41) | 5.67*** (4.03–7.30) |
| Secondary | 12.2*** (9.89–14.5) | 11.7*** (9.46–13.9) | 9.75*** (7.87–11.6) | 9.77*** (7.96–11.6) |
| High school | 10.8*** (9.27–12.4) | 10.0*** (8.34–11.7) | 8.71*** (6.94–10.5) | 8.26*** (6.51–10.0) |
| College | 15.5*** (12.3–18.6) | 14.6*** (11.5–17.7) | 12.1*** (9.25–15.0) | 11.5*** (8.49–14.4) |
| Current marital status | | | | |
| Married | Ref. | Ref. | Ref. | Ref. |
| Widowed | -6.22*** (-8.10 - -4.33) | -2.89*** (-4.74 - -1.03) | -2.56*** (-4.39 - -0.73) | -2.52*** (-4.34 - -0.69) |
| Others | -2.26 (-6.54–2.02) | -2.29 (-6.55–1.97) | -1.08 (-5.24–3.08) | -0.92 (-5.16–3.32) |
| Nutritional intake (> 4 times per day) | | | | |
| No | Ref. | | | Ref. |
| Yes | 1.59** (0.046–3.14) | | | -0.0016 (-1.37–1.37) |
| Body mass index | | | | |
| Underweight | Ref. | | | Ref. |
| Normal | 5.30*** (3.83–6.77) | | | 1.80*** (0.56–3.03) |
| Overweight | 8.39*** (6.04–10.7) | | | 2.18** (0.23–4.12) |
| Obese | 8.56*** (4.38–12.7) | | | 3.67** (0.52–6.81) |
| Physical activity | | | | |
| Vigorous | Ref. | | | Ref. |
| Moderate | 0.23 (-2.10–2.56) | | | -0.20 (-1.89–1.50) |
| Light | 1.20 (-0.81–3.20) | | | 0.39 (-1.29–2.07) |
| None | -2.05** (-3.79 - -0.31) | | | -1.34* (-2.77–0.088) |
| Self-rated health | | | | |
| Very good | Ref. | | | Ref. |
| Good | -4.63** (-9.11 - -0.15) | | | -2.63 (-5.90–0.64) |
| Moderate | -8.64*** (-12.9 - -4.33) | | | -3.93** (-6.98 - -0.87) |
| Bad | -12.0*** (-16.5 - -7.49) | | | -4.44** (-7.83 - -1.04) |
| Very bad | -9.98*** (-15.9 - -4.09) | | | -3.84 (-9.57–1.89) |
| Chronic conditions | | | | |
| Zero | Ref. | | | Ref. |
| Single | -0.81 (-2.39–0.78) | | | -0.48 (-1.67–0.71) |
| Two | -0.88 (-3.09–1.32) | | | -1.06 (-3.03–0.90) |
| Three and more | -2.93 (-6.64–0.78) | | | -2.56 (-5.66–0.54) |
| Smoking | | | | |
| Never | Ref. | | | Ref. |
| Currently not | -1.37 (-3.24–0.50) | | | -0.91 (-2.42–0.60) |

**Table 3** (continued)

| Variables | Unadjusted coefficients (95% CI) | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| | | **Adjusted coefficients (95% CI)** | **Adjusted coefficients (95% CI)** | **Adjusted coefficients (95% CI)** |
| Currently smoking | -1.08 (-2.81–0.65) | | | 0.35 (-0.98–1.68) |
| Wealth quintile | | | | |
| Poorest | Ref. | | Ref. | Ref. |
| Poor | 3.90*** (1.72–6.08) | | 1.33 (-0.35–3.00) | 1.21 (-0.50–2.92) |
| Middle | 4.90*** (2.86–6.94) | | 2.16** (0.40–3.92) | 1.95** (0.20–3.70) |
| Rich | 5.81*** (3.88–7.75) | | 2.14** (0.31–3.98) | 1.85** (0.020–3.68) |
| Richest | 10.2*** (8.09–12.4) | | 3.76*** (1.75–5.77) | 3.47*** (1.45–5.49) |
| Religion | | | | |
| Hindu | Ref. | | Ref. | Ref. |
| Muslim | -0.85 (-2.75–1.04) | | 2.18** (0.50–3.85) | 2.37*** (0.69–4.06) |
| Others | -4.13* (-8.44–0.19) | | -3.49 (-8.06–1.08) | -3.89* (-8.39–0.60) |
| Social group | | | | |
| Scheduled castes | Ref. | | Ref. | Ref. |
| Scheduled tribes | 1.28 (-1.03–3.60) | | 1.57 (-0.50–3.64) | 1.33 (-0.77–3.43) |
| Other backward classes | 4.50*** (2.23–6.76) | | 1.89* (-0.011–3.79) | 1.75* (-0.20–3.70) |
| Others | 6.19*** (3.84–8.54) | | 2.27** (0.21–4.32) | 2.20** (0.086–4.30) |
| Place of residence | | | | |
| Urban | Ref. | | Ref. | Ref. |
| Rural | -6.10*** (-8.32 - -3.88) | | -2.25** (-4.07 - -0.43) | -2.24** (-4.03 - -0.46) |
| States | | | | |
| Assam | Ref. | | Ref. | Ref. |
| Karnataka | -0.78 (-2.79–1.22) | | -3.53*** (-5.73 - -1.33) | -4.30*** (-6.50 - -2.10) |
| Maharashtra | 6.38*** (3.77–8.98) | | 4.02*** (1.99–6.05) | 2.77*** (0.79–4.76) |
| Rajasthan | 2.67*** (1.26–4.07) | | 1.67* (-0.0037–3.35) | 1.12 (-0.61–2.85) |
| Uttar Pradesh | 1.96** (0.42–3.51) | | -0.59 (-2.37–1.19) | -1.13 (-3.02–0.76) |
| West Bengal | 2.43*** (0.68–4.19) | | -0.20 (-2.17–1.77) | -0.49 (-2.57–1.59) |
| Constant | | 56.7*** (55.1–58.3) | 54.8*** (51.7–57.8) | 58.2*** (53.6–62.8) |
| Observations | | 3,000 | 3,000 | 2,909 |
| R-squared | | 0.224 | 0.273 | 0.296 |

Notes: Model 1 is adjusted for age, education and marital status; Model 2 is additionally adjusted for other socio-demographics such as household wealth quintile, religion, social group, place of residence and states; Model 3 is fully adjusted model, i.e., additionally adjusted for the health variables such as nutritional intake, body mass index, physical activity, self-rated health, chronic conditions and smoking status; CI: Confidence interval; *** $p<0.001$, ** $p<0.01$, * $p<0.05$

explore potential interventions to address cognitive disparities between urban and rural populations. The role of other background factors, such as chronic conditions, smoking status, wealth quintile, religion, social group, and states, did not show consistent significant effects on cognitive functioning. These findings suggest that the relationship between sleep and cognitive functioning may be less influenced by these background factors. However, it is important to consider that these factors may still indirectly impact cognitive health through their interactions with one's health and wellbeing.

### Limitations and direction for future research

It is important to acknowledge the limitations of this study. *First*, the data relied on self-reported measures, which may be subject to recall and social desirability biases. Future studies should consider objective measures of sleep to provide more accurate assessments. *Second*, there was a higher proportion of women in our sample without any formal education or primary education that would affect their cognitive function and influence our findings. *Third*, this study focused on a specific set of background characteristics, and there may be other factors, such as genetics, lifestyle factors, or comorbidities, that could influence the relationship between sleep and cognitive functioning. Additionally, the detrimental impact of poor sleep quality on cognitive functioning differently among men and women can be attributed to several contextual and environmental factors such as indoor air quality (Hunter et al. 2018; C.-C. Lo et al. 2022; Saenz et al. 2021), which needs further investigation. Similarly, sleep disturbances, such as frequent awakenings and fragmented sleep were not considered in this study, which could disrupt the restorative processes necessary for memory consolidation and neural repair (Cellini 2017; Zisapel 2007). As documented, inadequate sleep

**Table 4** Estimates from general linear models of cognitive functioning by background variables among older women SAGE- 2015

| Variables | Unadjusted coefficients (95% CI) | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| | | **Adjusted coefficients (95% CI)** | **Adjusted coefficients (95% CI)** | **Adjusted coefficients (95% CI)** |
| Sleep quality | | | | |
| Good | Ref. | Ref. | Ref. | Ref. |
| Moderate | -2.36*** (-3.79 - -0.92) | -1.30** (-2.59 - -0.017) | -1.33** (-2.64 - -0.028) | -0.99 (-2.27–0.29) |
| Poor | -3.15** (-5.79 - -0.52) | -1.98* (-4.30–0.34) | -2.29* (-4.60–0.020) | -1.74 (-4.16–0.67) |
| Sleep duration | | | | |
| Normal | Ref. | Ref. | Ref. | Ref. |
| Short | -2.72*** (-4.64 - -0.81) | -1.42 (-3.21–0.36) | -1.43 (-3.31–0.44) | -1.27 (-3.16–0.63) |
| Long | 1.04 (-0.42–2.50) | 0.20 (-1.05–1.45) | 0.16 (-1.11–1.42) | 0.53 (-0.71–1.76) |
| Age (in years) | | | | |
| 50–59 | Ref. | Ref. | Ref. | Ref. |
| 60–69 | -3.01*** (-4.46 - -1.56) | -1.70** (-3.02 - -0.37) | -1.74*** (-3.06 - -0.42) | -1.32** (-2.58 - -0.065) |
| 70–79 | -7.42*** (-8.98 - -5.86) | -4.99*** (-6.64 - -3.34) | -5.13*** (-6.76 - -3.50) | -4.20*** (-5.82 - -2.57) |
| 80+ | -9.60*** (-12.8 - -6.37) | -5.94*** (-9.35 - -2.53) | -6.37*** (-9.79 - -2.94) | -3.34* (-6.89–0.22) |
| Level of education | | | | |
| No formal education | Ref. | Ref. | Ref. | Ref. |
| Less than primary | 5.83*** (3.70–7.97) | 4.89*** (2.70–7.08) | 3.72*** (1.55–5.89) | 3.32*** (1.19–5.46) |
| Primary | 9.02*** (7.27–10.8) | 8.36*** (6.55–10.2) | 6.90*** (5.06–8.73) | 6.49*** (4.61–8.38) |
| Secondary | 11.7*** (9.34–14.0) | 10.6*** (8.17–13.0) | 8.64*** (6.07–11.2) | 7.75*** (5.08–10.4) |
| High school | 16.6*** (12.8–20.4) | 15.8*** (12.0–19.6) | 13.2*** (9.49–16.9) | 12.3*** (8.76–15.9) |
| College | 18.8*** (15.3–22.2) | 18.3*** (14.7–21.9) | 14.9*** (11.0–18.9) | 13.2*** (9.31–17.1) |
| Current marital status | | | | |
| Married | Ref. | Ref. | Ref. | Ref. |
| Widowed | -4.92*** (-6.23 - -3.61) | -1.97*** (-3.30 - -0.63) | -1.89*** (-3.24 - -0.55) | -1.54** (-2.83 - -0.26) |
| Others | -0.94 (-5.48–3.59) | -1.73 (-6.06–2.60) | -1.02 (-5.11–3.07) | 0.51 (-3.67–4.69) |
| Nutritional intake (> 4 times per day) | | | | |
| No | Ref. | | | Ref. |
| Yes | 3.59*** (1.97–5.20) | | | 2.83*** (1.27–4.40) |
| Body mass index | | | | |
| Underweight | Ref. | | | Ref. |
| Normal | 4.41*** (3.03–5.78) | | | 2.14*** (0.81–3.48) |
| Overweight | 8.38*** (6.22–10.5) | | | 3.25*** (1.13–5.38) |
| Obese | 9.44*** (6.84–12.0) | | | 4.04*** (1.34–6.73) |
| Physical activity | | | | |
| Vigorous | Ref. | | | Ref. |
| Moderate | 3.66*** (1.31–6.01) | | | 2.56** (0.32–4.81) |
| Light | 1.69 (-1.26–4.64) | | | 2.24 (-0.58–5.06) |
| None | 0.11 (-2.14–2.37) | | | 0.90 (-1.33–3.13) |
| Self-rated health | | | | |
| Very good | Ref. | | | Ref. |
| Good | -4.54** (-8.14 - -0.94) | | | -0.64 (-4.24–2.96) |
| Moderate | -7.23*** (-10.7 - -3.73) | | | -1.89 (-5.44–1.67) |
| Bad | -9.99*** (-13.7 - -6.32) | | | -2.93 (-6.72–0.86) |
| Very bad | -14.8*** (-21.6 - -7.97) | | | -2.62 (-10.5–5.27) |
| Chronic conditions | | | | |
| Zero | Ref. | | | Ref. |
| Single | 0.34 (-1.15–1.83) | | | -0.62 (-1.97–0.73) |
| Two | 2.28** (0.48–4.09) | | | 0.37 (-1.33–2.07) |
| Three and more | 2.36 (-1.46–6.19) | | | -1.62 (-5.05–1.80) |
| Smoking | | | | |
| Never | Ref. | | | Ref. |

**Table 4** (continued)

| Variables | Unadjusted coefficients (95% CI) | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| | | Adjusted coefficients (95% CI) | Adjusted coefficients (95% CI) | Adjusted coefficients (95% CI) |
| Currently not | -2.51** (-5.01 - -0.0070) | | | -1.09 (-3.20–1.01) |
| Currently smoking | -2.49*** (-4.35 - -0.64) | | | 1.16 (-0.57–2.89) |
| Wealth quintile | | | | |
| Poorest | Ref. | | Ref. | Ref. |
| Poor | 0.96 (-0.67–2.58) | | 0.35 (-1.37–2.06) | 0.28 (-1.40–1.96) |
| Middle | 2.91*** (0.84–4.99) | | 1.07 (-0.98–3.12) | 1.01 (-0.99–3.01) |
| Rich | 3.88*** (2.14–5.62) | | 1.36 (-0.40–3.12) | 0.68 (-1.10–2.45) |
| Richest | 9.33*** (7.48–11.2) | | 3.60*** (1.74–5.47) | 2.94*** (1.04–4.84) |
| Religion | | | | |
| Hindu | Ref. | | Ref. | Ref. |
| Muslim | 0.96 (-0.82–2.75) | | 1.78* (-0.052–3.61) | 1.53 (-0.32–3.38) |
| Others | 0.85 (-1.56–3.26) | | 1.52 (-0.67–3.70) | 1.26 (-0.97–3.49) |
| Social group | | | | |
| Scheduled castes | Ref. | | Ref. | Ref. |
| Scheduled tribes | -0.83 (-2.82–1.15) | | -0.53 (-2.52–1.45) | -0.69 (-2.68–1.30) |
| Other backward classes | 2.48** (0.58–4.37) | | 0.75 (-1.06–2.57) | 0.54 (-1.28–2.37) |
| Others | 4.42*** (2.49–6.34) | | 1.31 (-0.58–3.20) | 1.21 (-0.71–3.12) |
| Place of residence | | | | |
| Urban | Ref. | | Ref. | Ref. |
| Rural | -4.21*** (-6.09 - -2.33) | | -1.06 (-2.92–0.80) | -0.63 (-2.43–1.17) |
| States | | | | |
| Assam | Ref. | | Ref. | Ref. |
| Karnataka | 1.92* (-0.16–4.01) | | 1.75* (-0.32–3.82) | 0.86 (-1.25–2.97) |
| Maharashtra | 1.73 (-0.54–4.00) | | 1.29 (-0.66–3.24) | 0.90 (-1.07–2.86) |
| Rajasthan | -0.70 (-2.04–0.65) | | 0.69 (-0.89–2.28) | 0.31 (-1.34–1.97) |
| Uttar Pradesh | -0.56 (-2.15–1.02) | | 0.30 (-1.43–2.02) | 0.24 (-1.57–2.06) |
| West Bengal | 3.04*** (1.51–4.58) | | 2.12*** (0.53–3.71) | 2.41*** (0.64–4.17) |
| Constant | | 53.7*** (52.3–55.0) | 51.8*** (48.8–54.7) | 49.6*** (44.6–54.6) |
| Observations | | 3,364 | 3,364 | 3,249 |
| R-squared | | 0.193 | 0.210 | 0.231 |

Notes: Model 1 is adjusted for age, education and marital status; Model 2 is additionally adjusted for other socio-demographics such as household wealth quintile, religion, social group, place of residence and states; Model 3 is fully adjusted model, i.e., additionally adjusted for the health variables such as nutritional intake, body mass index, physical activity, self-rated health, chronic conditions and smoking status; CI: Confidence interval; *** $p<0.001$, ** $p<0.01$, * $p<0.05$

duration deprives the brain of sufficient time to engage in these crucial processes, leading to cognitive impairments over time (Lim and Dinges 2010; Lo et al. 2016), and these pathways should be considered in future studies.

Furthermore, sleep is closely intertwined with other physiological and psychological factors that influence cognitive health, such as inflammation, hormonal regulation, and emotional well-being (Tartar et al. 2015; Thompson et al. 2022). Finally, stressors, such as insufficient or lack of income (Muhammad et al. 2021), child rearing/caregiving burden (Muhammad and Srivastava 2022), and absence of adult children (Muhammad et al., 2022b), may induce mental strain, affect sleep and/or lead to cognitive deficits. Therefore, future research should delve deeper into the specific mechanisms through which sleep disturbances affect cognitive functioning in older adults, including potential gender differences. Thus, addressing the moderating factors identified in this study can shed light on direction for future research and enhancing the effectiveness of interventions targeting sleep and cognitive functioning.

## Conclusions

This study provides evidence for the significant association between sleep health and cognitive functioning in older Indian adults, especially older men, with poor sleep quality and shorter sleep duration being detrimental to cognitive health. The findings of this study also have important implications for healthcare providers and policymakers. Prioritizing the assessment and management of sleep disturbances in older adults is crucial for promoting healthy cognitive aging. Healthcare providers should routinely screen for sleep quality and age-appropriate sleep duration in their older adult patients and consider sex/gender-tailored sleep interventions as part of cognitive health management strategies. Educational programs aimed at improving cognitive health should be accessible and tailored to the diverse educational backgrounds of older adults. Social support interventions, particularly for widowed older women, can help mitigate the negative impact of widowhood on cognitive functioning. Additionally, comprehensive healthcare approaches that address overall health, including nutritional intake and self-rated health, should be integrated into cognitive health promotion strategies.

**Abbreviations**

| | |
|---|---|
| MCI | Mild cognitive impairment |
| WHO-SAGE | World Health Organization's Study on global AGEing and adult health |
| PSU | Primary Sampling Units |
| WHS | World Health Survey |
| PCA | Principal components analysis |
| aCoef | Adjusted Coefficients |
| CI | Confidence Interval |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41606-024-00100-z.

Supplementary Material 1

**Author contributions**

All authors fulfil the criteria for authorship. Conceived and designed the research paper: T.M.; analyzed the data: T.M.; Wrote the manuscript: T.M., A.A. and T.V.S; Refined the manuscript: T.M. and T.V.S. All authors read, reviewed and approved the manuscript.

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**Data availability**

The dataset analyzed for this study is available at data repository in https://iipsindia.ac.in/content/SAGE-wave-2

## Declarations

**Ethics approval and consent to participate**

The procedures undertaken in this study and the data collection processes were conducted ethically per the World Medical Association's Declaration of Helsinki. Ethical approvals were obtained for SAGE study from the Ethics Review Committee of the World Health Organization, the Ethics and Protocol Review Committee of the Ghana Medical School, Accra, Ghana, the Ethics Committee of the School of Preventive and Social Medicine, and the Russian Academy of Medical Sciences, Moscow, Russia. Approval was also obtained for the SAGE 1 study from the Ethics Committee of the Shanghai Municipal Centre for Disease Control and Prevention, Shanghai, China, Institutional Review Board of the International Institute of Population Sciences, Mumbai, India, and finally from the Research Ethics Committee of the Human Sciences Research Council, Pretoria, South Africa. These approvals also covered all procedures through which written informed consent was obtained from each participant. Confidential records of participants' consent were maintained by SAGE. Further, written informed consents for participating in the SAGE study were obtained from each participant.

**Consent for publication**

All authors consent to publish this research article.

**Competing interests**

The authors declare that there is no competing interest.

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## Publisher's Note