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Trajectories of sleep duration and quality and their association with mild cognitive impairment, frailty, and all-cause mortality

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ABSTRACT

Objectives: To identify longitudinal trajectories of sleep duration and quality and estimate their association with mild cognitive impairment, frailty, and all-cause mortality.
Methods: We used data from three waves (2009, 2014, 2017) of the WHO Study on Global Aging and Adult Health in Mexico. The sample consisted of 2722 adults aged 50 and over. Sleep duration and quality were assessed by self-report. Sleep trajectories were determined by applying growth mixture models. Mixed-effects logistic (mild cognitive impairment) and ordinal logistic (frailty), and Cox proportional hazards (all-cause mortality) models were fitted.
Results: Three classes for sleep duration ("optimal-stable," "long-increasing," and "short-decreasing") and quality ("very good-increasing," "very good-decreasing," and "moderate/poor stable") were identified. Compared to the optimal-stable group, the long-increasing trajectory had greater odds for mild cognitive impairment (odds ratio = 1.68, 95% CI: 1.01-2.78) and frailty (odds ratio = 1.66, 95% CI: 1.13-2.46), and higher risk for all-cause mortality (hazard ratio = 1.91, 95% CI: 1.14-3.19); and the short-decreasing class had a higher probability of frailty (odds ratio = 1.83, 95% CI: 1.26-2.64). Regarding the sleep quality, the moderate/poor stable trajectory had higher odds of frailty (odds ratio = 1.71, 95% CI: 1.18-2.47) than very good-increasing group.
Conclusions: These results have important implications for clinical practice and public health policies, given that the evaluation and treatment of sleep disorders need more attention in primary care settings. Interventions to detect and treat sleep disorders should be integrated into clinical practice to prevent or delay the appearance of alterations in older adults' physical and cognitive function. Further research on sleep quality and duration is warranted to understand their contribution to healthy aging.

Introduction

Sleep greatly influences the daily functioning and physical health of older adults and is one of the crucial elements in maintaining normal cognitive performance.[1] Evidence shows that sleep disturbances affect attention, reaction time, and overall social functioning.[2] Previous studies have also shown that sleep duration and quality are associated with physical and mental health in older adults and have important public health implications.[3]

Although there is no consensus regarding the definition of long and short sleep durations, epidemiological studies have suggested that a habitual sleep fewer than 6 hours can be considered short and greater than 9 hours long.[4] Long-duration (24%-38.4%) is more prevalent than short-duration sleep (0.8%-10.1%), according to a study conducted in 10 countries including adults aged 18 and more.[5] Regarding older adults in Mexico, a recent study reported prevalence of 13.3% for short and 38.5% for long sleep.[6] For sleep quality, studies in low- and middle-income countries, including Mexico, have reported a prevalence of poor sleep quality in the range of 7.7%-40.0% for the older adult population.[7]

Individuals at the extremes of sleep duration (short and long) and with poor sleep quality are particularly relevant for clinical practice and public health policies.[8] It has been shown that both conditions

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have detrimental physiological effects on the brain and profound biological stress on cells, organs, and the major regulatory systems of the body.[9] Recent evidence shows that sleep duration – analyzing one or both extremes – is significantly associated with cognitive decline,[10] premature mortality,[11] and the prevalence and incidence of frailty.[6,12] Associations of poor sleep quality and adverse health outcomes for the older adult population have also been reported. Studies have shown that poor sleep quality, or some of its indicators, is significantly associated with frailty, cognitive impairment, all-cause mortality, and suicidal ideation.[13-15]

Despite this evidence, most studies on sleep duration and quality have been cross-sectional, with limited longitudinal studies, particularly in low- and middle-income countries, and have assumed, explicitly or implicitly, that a single trajectory describes these characteristics for the population of older adults. Little is known about the heterogeneous longitudinal patterns of sleep duration or quality in older adults and how these trajectories are associated with adverse health events. Given the interindividual heterogeneity of sleep duration and quality and its temporal variations,[16] this study aimed to identify longitudinal trajectories of sleep duration and quality and estimate their association with mild cognitive impairment (MCI), frailty, and all-cause mortality in a nationally representative sample of older adults in Mexico.

Participants and methods

Study design and sample

We used data from three waves of the World Health Organization (WHO) Study on global AGEing and adult health (SAGE) in Mexico. A multi-country, longitudinal study, SAGE was based on nationally representative samples of individuals aged 50+ years in six countries: China, Ghana, India, Mexico, Russia, and South Africa. Details of the study design have been published elsewhere.[17] The SAGE-Mexico study and sample (cross-sectional and longitudinal) have been previously described.[18] Briefly, wave 1 (baseline data) was collected in 2009 with a sample of 2404 respondents. Wave 2 was carried out in 2014, with 618 new interviews, and wave 3 in 2017 with 2937 participants (including 255 new interviews). 3277 individuals were interviewed during the three waves. Because our aim was to identify longitudinal trajectories of sleep duration/quality, we included participants with at least two measurements. The analytical sample consisted of 2722 older adults, with an overall response rate of 83% (Fig. 1). Baseline differences between the final sample and excluded participants were observed. Older adults without follow-up measurements were older with a higher prevalence of frailty, disability, and multimorbidity ($P < .05$).

Sample for mortality data

A description of the sample for the analysis of all-cause mortality has recently been published,[19] so we mention here the general characteristics. The individuals were included if they had measurements for waves 1 and 2, and their death occurred between waves 2 and 3. Given that the cohort incorporates new individuals (with rolling admissions), older adults with measurements in waves 2 and 3 were considered with delayed entry. Information on the date of death was not available for 158 individuals, so the analytical sample for this analysis included 2564 older adults. Table S1 (Supplementary Material) shows the different settings and their sample size.

Measures

Sleep duration and quality

Participants were asked their sleep duration on each of the preceding two nights, not including daytime sleep. The duration values across two nights were averaged to create a summary measure of sleep length for each wave. Sleep quality was assessed by the following question "Please rate the quality of your sleep last night. Was it very good, good, moderate, poor, or very poor?" This variable was coded as very good (1) to very poor (5). Both definitions have been used in previous studies with data from the SAGE study.[20]

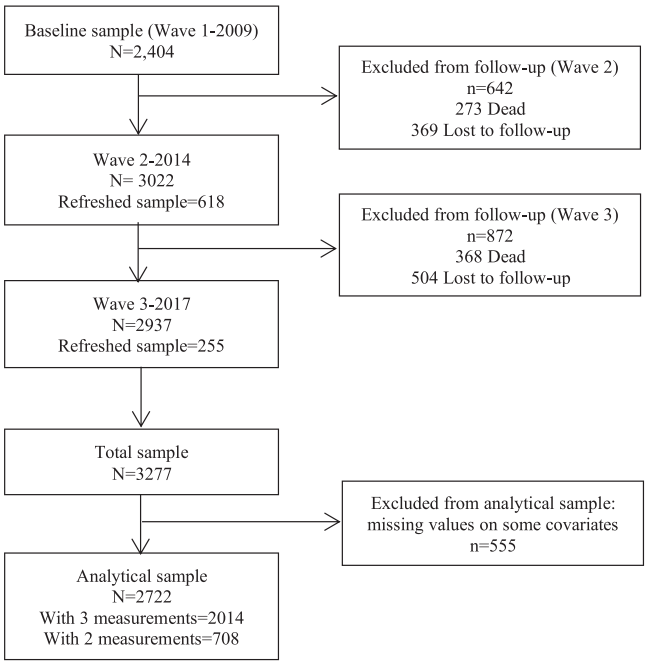

Fig. 1. Flow diagram for the analytical sample

Mild cognitive impairment

We used an algorithm based on recommendations from the National Institute of Aging and the Alzheimer's Association,[21] which has been accounted of in a recent study with the SAGE data, to generate the MCI variable.[22] The older adults who met all the following criteria were considered to have MCI:

a) Concern regarding a change in cognition. Participants were asked the following questions: "How would you best describe your memory at present?" and "Compared to 12 months ago, would you say your memory is now better, the same or worse than it was then?" to evaluate this item. Those OA who reported "bad" or "very bad" and "worse" were considered to have concern with cognition.
b) Evidence of impairment in one or more cognitive domains were assessed (based on a < −1 SD cut-off after adjustment for level of education and age) with immediate and delayed verbal recall, forward and backward digit span and verbal fluency tests.
c) Independence in activities of daily living (ADLs) evaluated with Katz scale.
d) Not demented participants who could not take the survey due to a severe cognitive impairment. A close family member or caregiver reported whether the older adult had frequent episodes of memory loss or spatial/temporal disorientation.

Frailty

Frailty status was assessed using the criteria proposed by Fried[23] which covers five components: weight loss, exhaustion, low physical activity, slow walking speed, and weakness. Respondents were considered frail if they met three or more of these criteria, prefrail if they met one or two, and not frail or robust if they met none of the

above criteria. A detailed description of the measurement of frailty in the SAGE sample have been published elsewhere.[24]

All-cause mortality

Data extracted from interviews in wave 3 (2017) included information on death (from any cause) using the WHO verbal autopsy instrument.[19] Follow-up time was defined as the interval between baseline interviews (either individuals whose risk began in 2009 or with a delayed entry in 2014) and the third wave for censored data. The date of death was also recorded providing information on the survival time.

Covariates

The following health and socioeconomic variables were used as potential confounders: sex (1 = female), age, number of years of formal education, marital status (with couple = 1), having a paid job, and health insurance (yes = 1). Socioeconomic status (SES) of the household was derived using the WHO standard approach to estimate permanent income from household ownership of durable goods, dwelling characteristics (type of floors, walls, and cooking stove), and access to services such as water, sanitation, and electricity.[25] SES was included as a continuous variable, with higher values indicating better SES. Data on usual home medication regimen were recorded based on personal interview. The number of drugs usually consumed in the last 30 days was determined from the prescriptions that the participants took at home. As we were interested in sleep patterns and their association with outcomes like MCI, the use of opioids, anxiolytics, sedatives, and stimulants was considered. Multimorbidity was included as a dichotomous variable defined as the presence of two or more chronic noncommunicable conditions from the list of nine chronic diseases included in the SAGE study. The operational definitions of these diseases have been published elsewhere.[26] Functionality was evaluated with the following two variables: limitations in ADL and instrumental activities of daily living (IADL). Ten questions from the World Health Organization Disability Assessment Schedule (WHODAS) II questionnaire were used for assessing any difficulties in performing ADL (dressing [including putting on shoes and socks), eating [such as cutting up your food], using the toilet [including getting up and down], bathing and showering, and getting in and out of bed) and IADL (preparing a hot meal, shopping for groceries, making telephone calls, taking medications, and managing your money, such as paying your bills and keeping track of expenses) in the preceding 30 days. Respondents were considered as "with limitation" if they reported any difficulties in performing at least one of the five daily activities listed above for ADL or IADL, respectively. Physical activity was assessed with the Global Physical Activity Questionnaire (GPAQ) classifying older adults in three categories (low, moderate, and high physical activity) based on reported time spent in moderate or vigorous activities during work, recreational/leisure time, and transportation.[27] Tobacco use (never; ever smoked, no longer; current smoker, not daily; current smoker, daily), and alcohol consumption (never; ever drinker, no longer; current drinker, low risk; current drinker, high risk) were self-reported.

Statistical analysis

Baseline characteristics are presented in percentages and means (standard deviation) as appropriate. Health and sociodemographic characteristics related to longitudinal trajectories of sleep duration were compared using chi-square or ANOVA tests. Growth mixture modeling (GMM) was used to investigate the longitudinal trajectories of sleep duration and quality.[28] GMM is useful since it provides information regarding the growth factors of each different trajectory. The intercept and slope (growth factors) are interpreted as usual in longitudinal modeling: the level of outcome variable when time is equal to zero and the rate of change in the outcome over time, respectively. A detailed description of the GMM procedure and the statistical analysis is reported in the Appendix 2 of the Supplementary Material.

Given that we have repeated measurements of MCI and frailty (both outcomes were measured in the three waves), their association with sleep trajectories (duration and quality) was estimated using logistic mixed-effects (MCI) and ordinal logistic mixed-effects (frailty) models. In particular, a random intercept model with subject ID as a random effect was adjusted to consider the correlation induced by the repeated measures.

The association between sleep trajectories and all-cause mortality was estimated using the Cox proportional hazards model. Regarding this analysis, a potential bias could affect the results given that not all individuals start to be at risk simultaneously because of delayed entry.[29] Then, we incorporated the delayed entry information in our statistical analysis following the proposal of Lamarca to analyze left-truncated data using age as the time scale.[30] The survival time was considered as the elapsed time from age 50 until the event of interest. We also used clustered standard errors to account for correlation between repeated measurements within individuals.

All models were adjusted using the covariates described above and the follow-up time. Odds and hazard ratios, and 95% confidence intervals, were reported. Models for GMM were estimated in Mplus v8.5 (Muthén LK, Muthén BO. Mplus User's Guide. Eighth. Los Angeles, CA: Muthén & Muthén; 2017), and Stata v17.0 (StataCorp. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC; 2021) was used to model the association between sleep trajectories and the outcomes described above.

Statement of ethics

All procedures performed involving human participants were in accordance with the ethical standards of the Ethics Committee (CI/2013/550), National Institute of Public Health, Cuernavaca, Mexico, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all participants in the study. This study was conducted following the STROBE guidelines for reporting cohort studies (STROBE checklist is reported in Appendix 3 of the Supplementary Material).

Results

At the baseline, the sample was constituted of 2404 older adults. The mean sleep duration was 7.2 hours (SD = 1.5). For sleep quality, 18.1%, 62.8%, 14.5%, 3.7%, and 0.9% reported very good, good, moderate, poor, or very poor quality, respectively. 61.7% were female, and the mean age was 67.5 (SD = 10.3).

Trajectories of sleep duration and quality

Results of the GMM modeling favored the three-class model for both duration and quality of sleep. Regarding sleep duration, the first class was identified as "optimal-stable" with a baseline mean of 7.6 hours sleep duration and a slight decreasing slope ($\beta = -0.05$, $p < .01$). This group had 2178 individuals (80% of the sample). The second class, "long-increasing," had the higher baseline sleep duration (9.3 hours) and an increasing trajectory ($\beta = 0.11$, $p < .01$). This class had 272 individuals (10% of the sample). The third class, "short-decreasing" had the lowest baseline sleep duration (5.7 hours) and a steep decreasing trajectory ($\beta = -0.16$, $p < .01$), with 272 participants (10%). As for sleep quality, the first group, "very good-increasing," was composed of 381 older adults (14%), with the highest and increasing proportion of individuals reporting very good sleep quality. The second group, "very good-decreasing," had 2069 individuals (76%), with the highest baseline proportion of subjects

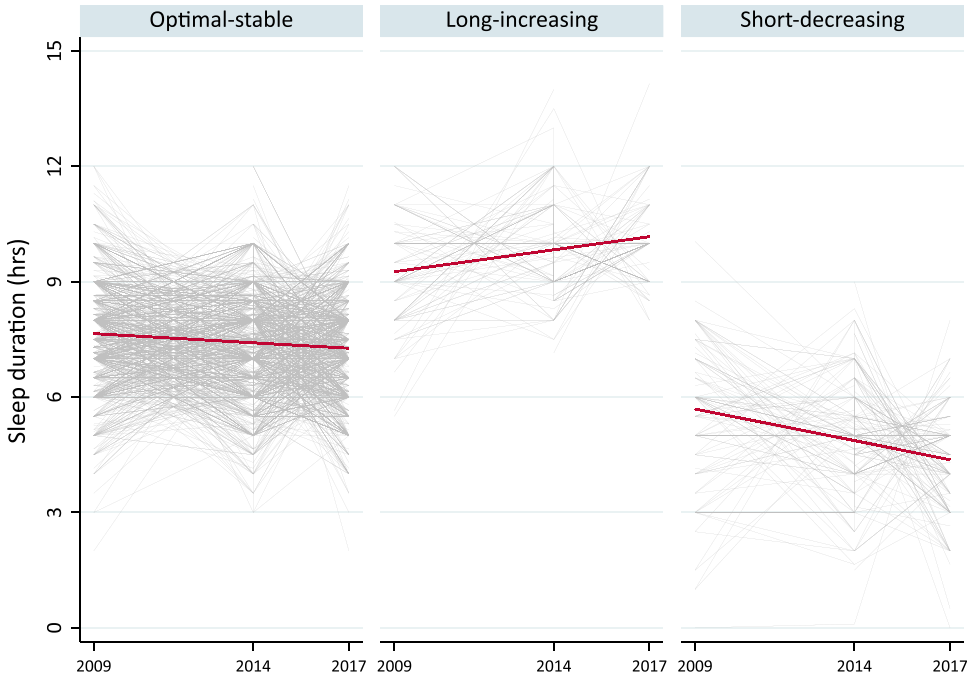

Fig. 2. Trajectories of sleep duration for the 3-class model

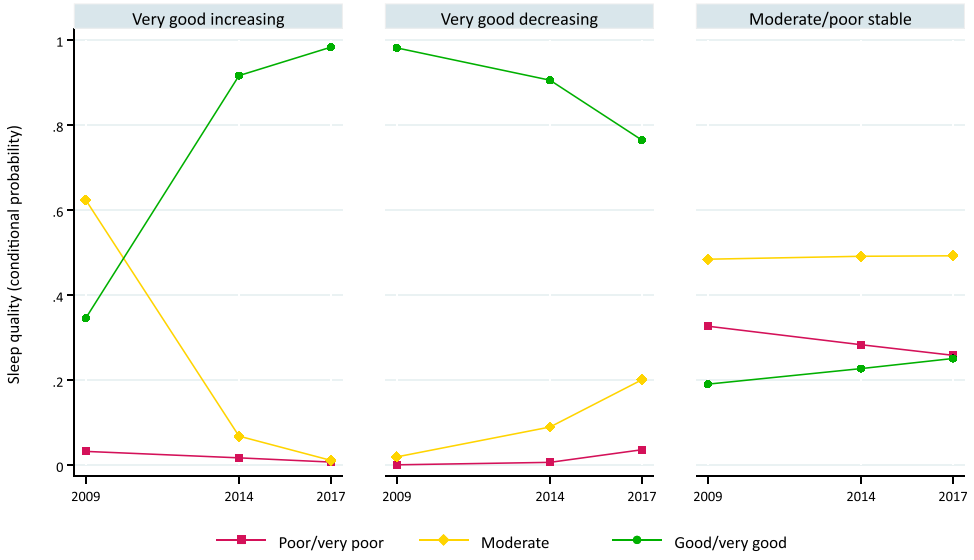

Fig. 3. Trajectories of sleep quality for the 3-class model

reporting very good sleep quality and a steep decreasing trajectory for this category. Finally, the third group, "moderate/poor stable," had 272 older adults (10%), with the highest proportion of individuals reporting a moderate or poor sleep quality, and a stable trajectory. Figures 2 and 3 depict the longitudinal trajectories for sleep duration and quality. A detailed description of the results for the GMM is provided in the Appendix 4 of the Supplementary Material.

Table 1 shows baseline health and sociodemographic characteristics by sleep duration trajectories. In comparison to individuals in class 1 (optimal-stable), older adults in classes 2 (long-increasing) and 3 (short-decreasing) had higher prevalence of MCI (p-value < .01). They also displayed a lower proportion of nonfrail individuals (p-value < .01). Regarding sleep quality trajectories, older adults in the moderate/poor stable class had a higher prevalence of MCI (p < .01) and frailty (p < .01) than their counterparts in the very good increasing and very good decreasing classes (Table S4, Supplementary Material).

Associations of sleep trajectories with MCI, frailty, and all-cause mortality

The associations of sleep trajectories (duration and quality) with the distal outcomes are shown in Table 2. Regarding MCI, the only significant association was observed for the long-increasing trajectory (sleep duration), which had the higher odds of MCI in comparison with the optimal-stable one (odds ratio [OR] = 1.68; 95% CI: 1.01-2.78).

About frailty, the groups long-increasing and short-decreasing had a higher likelihood of frailty than the optimal-stable class (OR = 1.66; 95% CI: 1.13-2.46; and OR = 1.83; 95% CI: 1.26-2.64, respectively) concerning the sleep duration. For the sleep quality, the moderate/poor stable group

Table 1
Baseline sociodemographic and health characteristics according to sleep duration trajectories

	Optimal-stable n = 2178 (80%)	Long-increasing n = 272 (10%)	Short-decreasing n = 272 (10%)	*p*-value[a]
Outcomes				
Mild cognitive impairment	9.3	12.8	17.1	< .01
Frailty				< .01
Nonfrail	38.4	30.4	29.0	
Prefrail	54.7	55.6	64.7	
Frail	6.9	14.1	6.3	< .01
All-cause mortality	6.2	11.1	2.6	< .01
Sociodemographics				
Sex (female = 1)	60.3	68.9	58.4	.12
Age	64.8 (9.4)	68.4 (9.7)	62.8 (8.9)	< .01
Years of formal education	5.3 (4.6)	4.0 (3.8)	4.8 (4.0)	< .01
Marital status (with couple = 1)	66.2	56.4	61.6	.04
Paid job	32.6	24.8	30.5	.15
Health insurance	78.9	80.3	85.6	.11
Socioeconomic status (assets index)	0.0 (1.2)	0.2 (1.2)	0.3 (1.1)	< .01
Health				
Number of medications	0.2 (0.5)	0.2 (0.5)	0.2 (0.6)	.82
Multimorbidity	53.4	56.3	67.9	< .01
Activities of daily living limitations	32.9	33.8	38.4	.30
Instrumental activities of daily living limitations	6.3	14.3	8.9	< .01
Lifestyle behaviors				
Physical activity				
Low	41.8	44.4	39.4	
Moderate	27.4	22.9	27.7	
High	30.8	32.6	32.9	.77
Tobacco				
Never	67.9	70.7	66.8	
Ever smoker, no longer	16.5	14.3	18.9	
Current smoker, not daily	5.1	3.8	6.3	
Current smoker, daily	10.6	12.3	7.9	.74
Alcohol consumption				
Never	47.3	53.8	41.6	
Ever drinker, no longer	40.1	38.6	47.4	
Current drinker (low risk)	8.7	5.3	8.4	
Current drinker (high risk)	3.5	2.3	2.6	.31

Cells are means (sd) or percentages.
[a] Chi-square or ANOVA tests.

showed higher odds of frailty (OR = 1.71; 95% CI: 1.18-2.479) compared to the very good increasing group.

For all-cause mortality data, the median duration of follow-up was 2002 days (5.5 years), with an interquartile range of 1196 days. In total, 368 deaths were observed, equivalent to a mortality rate of 26.1 per 1000 person-years. The long-increasing group had a higher risk of dying than the optimal-stable group of sleep duration (hazard ratio = 1.91; 95% CI: 1.14-3.19). Nonsignificant associations were observed for the classes of sleep quality.

Discussion

The results of this study provide evidence on the sleep duration and quality trajectories and their association with MCI, frailty, and

Table 2
Longitudinal associations of mild cognitive impairment, frailty, all-cause mortality, and sleep trajectories[a]

	Mild cognitive impairment		Frailty		All-cause mortality	
	OR	95% CI	OR	95% CI	HR	95% CI
Sleep duration						
Optimal-stable	Ref.		Ref.		Ref.	
Long-increasing	1.68	(1.01; 2.78)	1.66	(1.13; 2.46)	1.91	(1.14; 3.19)
Short-decreasing	1.30	(0.79; 2.15)	1.83	(1.26; 2.64)	0.63	(0.26; 1.55)
Variance components						
Subject	1.49	(1.04; 2.14)	1.35	(1.03; 1.77)		
Intraclass correlation						
Subject	0.31	(0.24; 0.39)	0.29	(0.24; 0.35)		
Sleep quality						
Very good increasing	Ref.		Ref.		Ref.	
Very good decreasing	0.74	(0.50; 1.10)	0.93	(0.69; 1.24)	1.95	(0.90; 4.21)
Moderate/poor stable	1.20	(0.74; 1.96)	1.71	(1.18; 2.47)	1.56	(0.61; 3.98)
Variance components						
Subject	1.61	(1.06; 2.45)	1.40	(1.07; 1.82)		
Intraclass correlation						
Subject	0.33	(0.24; 0.43)	0.30	(0.25; 0.36)		

HR, hazard ratio; OR, odds ratio.
[a] Models adjusted for covariates shown in Table 1.

all-cause mortality, among a representative sample of older adults in Mexico with longitudinal data that encompasses a 9-year follow-up. For sleep duration, prolonged and increasing sleep was consistently found to be associated with an increased risk of all-cause mortality and increased likelihood of frailty and MCI, even controlling for a broad set of covariates related to health, lifestyle behaviors, and functionality. While short and decreasing sleep was only associated with the presence of frailty. For the sleep quality trajectories, older adults with a poor/moderate quality stable trajectory showed a higher probability of frailty.

Mild cognitive impairment

Regarding the association between sleep duration and MCI, our results confirm what has been reported in a systematic review that increased sleep duration is associated with worse cognitive function.[31] Additional epidemiological evidence has shown that extreme sleep duration at baseline (≤4 or ≥10 hours per night) was associated with more rapid cognitive decline.[32] Another study with older Mexican adults also found that increased sleep duration was significantly associated with a greater decline in cognitive function during a 3-year follow-up.[33]

Our study found no significant association between sleep quality trajectories and MCI, confirming what a recent meta-analysis reported regarding sleep quality and the risk of cognitive disorders.[10] Sleep duration is likely more important than quality for prevalent or incident MCI, although subsequent studies should confirm or rule out this hypothesis. Additionally, sleep quality should be more comprehensively assessed through objective indicators related to cognitive and physical performance in older adults measured by polysomnography (slow-wave sleep, rapid eye movement sleep, and sleep continuity) or actigraphy (sleep efficiency and wake after sleep onset time).[34]

Regarding the mechanisms that could explain the association between sleep duration and cognitive function, several pathways have been postulated. First, the activity of inflammatory pathways such as Interleukin 6 (IL6) and C-reactive Protein could increase due to excessive sleep duration, and these inflammatory disorders could mediate age-related cognitive decline.[2] Also, a similar biological pathway has been postulated about the mediating role of chronic low-grade inflammation linking sleep and cognitive decline.[32] Second, longer sleep duration could reflect the existence of other sleep disorders, such as disturbed breathing during sleep.[2] Third, the longer time in a recumbent position may increase the span with high intracranial pressure and subsequently alter cerebrospinal/interstitial fluid dynamics and reduce β-amyloid clearance, which in turn could be related to the pathophysiology of cognitive dysfunction.[2] Again, the objective measures of sleep are in need since during natural sleep (observed even in anesthetized mice), there is an increase in interstitial space resulting in increased convective exchange of cerebrospinal fluid with interstitial fluid that finally significantly increases the glymphatic clearance of amyloid-beta.[35]

Frailty

To the best of our knowledge, this is the first study that analyzes the relationship between sleep duration and quality trajectories with frailty in older adults and reports a significant association. Even so, previous studies, not analyzing sleep trajectories, have reported mixed results. A cohort study with older Mexican adults residing in rural areas reported that extremes of sleep duration were associated with prevalent and incident frailty. Specifically, baseline values of short (≤5 hours) and long (≥9 hours) of nocturnal sleep were associated with an increased risk of developing frailty over 4.4-year follow-up.[6] A similar result was reported in a cross-sectional study with community-dwelling older Japanese adults.[36] However, other cross-sectional and cohort studies have not observed significant associations between sleep duration and the presence of frailty.[37] A recent cohort study analyzed sleep associations with frailty and mortality using actigraphic sleep parameters among a sample of older American adults. Actigraphically measured sleep duration was not associated with frailty or mortality. Nonetheless, greater sleep fragmentation (ie, higher frequency and duration of awakenings throughout the night) increased the risk of frailty and mortality over a 5-year follow-up.[12] Meanwhile, other studies have found a significant association with short sleep duration or prolonged duration.[38] Regarding sleep quality trajectories, we found that a low sleep quality trajectory was associated with frailty status. This result is consistent with previous evidence from cross-sectional studies, suggesting that a multi-dimensional sleep health index,[39] or poor sleep quality, or any of its parameters, increases the probability of frailty.[40]

A potential mechanism underlying the association between short sleep duration and frailty involves alterations in the neuroendocrine regulation. Reductions in testosterone levels have been observed in people who report few hours of sleep, along with chronic inflammation, increased levels of oxidative stress, and imbalances in growth hormone secretion.[9,40] For prolonged sleep duration, the association with frailty may be explained by biologically longer nights, which means periods with elevated melatonin and cortisol levels and lower body temperature,[41] which in turn could affect the immune system and increase the likelihood of weakening.[42] Older adults who sleep a lot have reported lower levels of daily physical activity, lower muscle strength, and slow gait speed.[43]

All-cause mortality

The results for the association between the long-increasing sleep trajectory and mortality risk confirm what has been previously reported. A systematic review, that included a meta-analysis of 27 cohort studies with more than 70,000 older adults, with a follow-up of 3.4-35 years, found that long sleep duration (> 8 hours) was associated with a higher risk of all-cause mortality (RR = 1.33; 95% CI: 1.24-1.43).[44] Another systematic review, including 47 studies with a sample of 3,582,016 individuals, showed that a long duration of night sleep (> 7 hours) increases the risk of dying by 13% for each additional sleep hour.[45] A recent study analyzed the association between longitudinal sleep duration patterns, all-cause mortality, and cardiovascular disease incidence in a prospective cohort with a 4-year follow-up period. Results showed that low-stable and normal-decreasing duration trajectories were associated with an increased risk of all-cause mortality.[46] However, it is important to highlight that the results in these cohort studies included 18-year-old individuals. Therefore, they are not specific for the older adult population, implying that these comparisons must be taken cautiously.

Regarding sleep quality trajectories, we did not find a significant association between poor sleep quality and all-cause mortality. This result is similar to the reported in a recent meta-analysis that included 10 studies with the adult and older adult population, where it was reported that poor sleep quality and all-cause mortality were not associated.[47] A possible explanation for this finding is that the relationship between sleep quality and mortality is not direct but is mediated by other health conditions. Evidence indicates, for example, that poor sleep quality increases the risk of cardiovascular disease, which may increase the risk of death.[47] However, few studies among older adult populations have addressed the specific association between sleep quality and mortality, and the results have been inconclusive.[48] The discrepancies in the results could be explained by the definition of the older adult population or by the variability in the questions used to assess sleep quality. In this study, sleep quality was assessed by self-report based on one question, which probably limited the possibility of exploring more specific aspects of sleep quality or discriminating by the presence of sleep

disorders that, according to the available evidence, are associated with all-cause mortality.[4]

The potential mechanisms explaining the relationship between prolonged sleep duration and all-cause mortality have not been fully elucidated.[45,46] This association could be confounded by poor health status or an uncontrolled chronic disease.[44] However, in this study, a large number of covariates of health, lifestyles, and functionality were used. The association could also be explained by the increase in inflammatory markers which are associated with prolonged sleep, since it has been reported that prolonged sleep is related to sleep fragmentation,[45] the presence of obstructive sleep apnea and insomnia.[44]

Traits of sleep duration and quality

The results of our study show that 80% of the older adults had optimal or normal sleep duration trajectory (6-8 hours), which coincides with previous studies that have reported that most older adults (> 50%) report optimal levels. A longitudinal study of older Americans found that 67% of their sample had normal duration,[49] and another study of British older adults, with 25 years of follow-up, reported optimal duration for 82% of participants.[50] While a cross-sectional study with Chinese older adults, using baseline data from the West China Health and Aging Trend study, found that 67% of individuals had normal sleep duration.[51]

In our study, 10% of the participants had a stable moderate/poor sleep quality trajectory. Compared with sleep duration, the results for sleep quality in old age are more heterogeneous due to the nature of the measurement (objective vs. subjective), the instruments or scales used, and even the sleep parameters used. Consistent with this, previous studies have reported a prevalence of 21% and 34% poor sleep quality among older adults in China[52] and 18% in the United States.[53] Furthermore, a recent systematic review, with studies that included healthy older adults, reported a prevalence of poor sleep quality ranged 11%-64%.[54]

Strengths and limitations

This study has several strengths. Firstly, it is the first study in Latin America that analyzes the longitudinal trajectories of sleep duration and quality and investigates their link with frailty, MCI, and all-cause mortality among the older adult population. Secondly, a follow-up period (9 years) of a nationally representative sample of older adults in Mexico is incorporated, allowing the effects of sleep duration and quality to be captured. Thirdly, our models incorporate a significant number of covariates (health, demographics, lifestyles, and functionality), thereby reducing the presence of residual confusion. And fourth, the study identifies modifiable risk factors - sleep duration and quality - that could play a key role in interventions to prevent or delay MCI, frailty, and all-cause mortality. However, the study results should be interpreted in the presence of some limitations. First, our study has focused on the temporal relationship of sleep disorders (duration and quality as main exposures) and MCI, frailty, and death as outcomes. Nevertheless, these relationships can be more complex (especially for MCI and frailty), being particularly bidirectional, so in future studies, these complex relationships could be explored in even greater depth. Second, the duration and quality of sleep have been measured through older adults' self-reporting due to the inherent complexity of having a nationally representative sample and the high costs that objective measurements, such as polygraphy or polysomnography, would represent. Third, the study does not incorporate other sleep disorders or daytime napping, which have been reported to be associated with all-cause mortality and mortality associated with cardiovascular risk. Fourth, the alterations in the sleep-wake cycle, related to longer or shorter durations and poor quality, could be a marker rather than a cause of the neuropathological and physical changes related to cognitive decline and frailty.

Conclusions

This study shows evidence that a long-increasing sleep trajectory (≥9 hours) is significantly associated with MCI, frailty, and all-cause mortality. At the same time, the short-decreasing sleep trajectory is related to the presence of frailty. Additionally, the persistence of poorer sleep quality, represented by the stable poor/moderate trajectory, represents a risk for frailty. These results have important implications for clinical practice and public health policies aimed at older adults since sleep duration and quality are valuable measures due to their cost-effectiveness (low cost), low intrusion for participants, and intuitive interpretation. Highlighting the concepts of sleep quality and duration to analyze their independent and combined impact on health outcomes in older adults is necessary to understand the contribution of healthy sleep to public health. Given that sleep disorders have generally been excluded in the design and implementation of interventions or programs to prevent or delay the appearance of alterations in older adults' physical and cognitive function, early interventions should be implemented to improve the quality and quantity of sleep. In particular, nonpharmacological interventions may be effective at the population level due to the low probability of adverse effects. Recommended interventions such as exercise, aromatherapy, auricular acupressure, cognitive behavioral therapy, meditation and stimulation therapy have shown their effectiveness in culturally and socioeconomically diverse contexts.[55] On the other hand, the effects of pharmacological treatments are modest and their continued use can reduce their effectiveness and safety [REF]. Further robust studies (ie, clinical trials) are required to generate evidence on the efficiency, effectiveness, and safety of drug treatments. Meanwhile, the administration of medications for the treatment of sleep disorders in older adults should be reviewed frequently, and even limit pharmacological intervention as far as practicable.[56] This fact is relevant because the evidence indicates that adults who meet the recommended hours of sleep at age 20 have a life expectancy of 2.6 years longer than those with prolonged sleep.[8]

Author contributions

ASR and BME contributed to the conception and design of this research. ASR conducted the data analyses and interpreted the data. ASR and BME wrote the first and subsequent drafts of the paper. ASR, BME, KMT, and SGZ contributed to the interpretation of findings and substantially revised the manuscript for important intellectual content.

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Data availability

The datasets analyzed during the current study are available in the WHO repository, https://www.who.int/data/data-collection-tools/study-on-global-ageing-and-adult-health/sage-waves.

Declaration of conflicts of interest

None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.sleh.2023.12.002.

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