Research Square

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Joint associations of sleep duration and multimorbidity with all-cause mortality in US adults

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Abstract

Background

Sleep duration has been linked to mortality in numerous studies, typically showing U- or J-shaped associations. However, most research evaluates sleep in isolation or within single disease contexts, without considering the broader burden of multimorbidity. We examined the joint association of sleep duration and multimorbidity severity with all-cause mortality in a nationally representative sample of US adults.

Methods

We conducted a prospective cohort study using data from the 2004 National Health Interview Survey linked to the National Death Index through 2019. Adults aged ≥ 18 years with complete data were included (n = 29,997). Sleep duration was categorized as 1–4, 5–6, 7–8 (reference), 9, and ≥ 10 hours. Multimorbidity burden was assessed using the Charlson Comorbidity Index (CCI), categorized as none and tertiles among those with ≥ 1 condition. Survey-weighted Cox proportional hazards models estimated hazard ratios (HRs) and 95% confidence intervals (CIs) for the joint association between sleep duration and multimorbidity. Models were adjusted for sociodemographic and behavioral covariates. Sensitivity analyses excluded deaths occurring within the first 12 months of follow-up.

Results

During up to 15 years of follow-up, mortality risk increased progressively with higher multimorbidity burden across all sleep-duration categories. In crude models, both short and long sleep were associated with elevated mortality compared with 7–8 hours. After adjustment, associations for short sleep were attenuated, whereas long sleep remained consistently associated with higher mortality. Compared with adults sleeping 7–8 hours with no multimorbidity, those reporting ≥ 10 hours of sleep in the highest CCI category had substantially elevated mortality risk (adjusted HR 11.15, 95% CI 6.54–19.01). Results were similar after excluding deaths within the first year of follow-up.

Conclusions

Sleep duration and multimorbidity jointly influence mortality risk among US adults. Prolonged sleep, particularly among individuals with higher multimorbidity burden, was strongly associated with mortality. These findings highlight the importance of considering multimorbidity when interpreting sleep–mortality relationships.

Background

Sleep is a fundamental determinant of health, yet a substantial proportion of adults do not achieve the recommended 7–8 hours of sleep per night.[1–4] A growing body of prospective evidence suggests that both short (< 7 hours) and long (≥ 9 hours) sleep durations are associated with increased risks of chronic disease and premature mortality.[1–9] These associations often follow a U- or J-shaped pattern and have been reported across diverse populations and settings.[1, 3, 4, 7, 9]

Several biological mechanisms may underline these relationships. Inadequate or fragmented sleep has been linked to immune dysregulation, systemic inflammation, metabolic disturbance, and alterations in autonomic and circadian regulation.[10–14, 22–24] Short sleep has been associated with heightened cortisol activity, elevated blood pressure, insulin resistance, and adverse lipid profiles, which can increase cardiometabolic risk.[10–14, 22, 23] Prolonged sleep, in contrast, is frequently interpreted as a marker of underlying morbidity or vulnerability, including cardiovascular disease, depression, frailty, and cancer-related fatigue, that may independently increase mortality risk.[11, 16, 20, 22, 24–26]

While the relationship between sleep duration and mortality has been widely studied, much of the existing literature has emphasized single conditions or narrow disease clusters, such as cardiovascular or cardiometabolic diseases.[3, 4, 7, 23, 29] By contrast, multimorbidity, defined as the co-occurrence of multiple chronic conditions within an individual, is highly prevalent and rising in many populations.[15, 19, 27, 29] Multimorbidity reflects not only disease count but also disease complexity and severity, and it may meaningfully shape the sleep–mortality association.[15, 19, 27, 29] However, prior studies that considered multimorbidity have often relied on simple condition counts, nonstandard definitions, or fixed groupings that do not capture severity and limit comparability.[29–32]

A practical implication is that the public health message “sleep 7–8 hours” may not translate uniformly across people living with different levels of comorbidity burden. Yet few population-based US studies have quantified the *joint association* of sleep duration and multimorbidity severity with mortality using validated comorbidity indices, nationally representative sampling weights, and formal interaction modeling. The Charlson Comorbidity Index (CCI) provides a validated, prognostic measure of comorbidity severity and has been widely used in survival and outcomes research.[33–35] Still, evidence remains limited on whether (and how strongly) mortality risks at the extremes of sleep duration differ across CCI-defined strata, and whether these associations persist after accounting for sociodemographic and behavioral factors and potential reverse causation from subclinical disease.

In this context, the aim of this study was to examine the joint association of sleep duration and multimorbidity severity with all-cause mortality in a nationally representative sample of US adults from the 2004 National Health Interview Survey linked to mortality through 2019, using survey-weighted Cox models. Sleep duration was modeled in clinically relevant categories, multimorbidity was quantified using CCI categories, and interaction terms were used to estimate stratum-specific hazard ratios relative to adults sleeping 7–8 hours with no multimorbidity. We additionally conducted sensitivity analyses excluding deaths within the first 12 months of follow-up to reduce concerns about reverse causation. We hypothesized that multimorbidity would modify the sleep–mortality relationship, such that the excess mortality risk associated with short and long sleep would be amplified among adults with higher comorbidity burden.

Methods

Study design and data source

This prospective cohort study used data from the 2004 National Health Interview Survey (NHIS), a nationally representative cross-sectional survey of the civilian, noninstitutionalized population of the United States conducted annually by the National Center for Health Statistics (NCHS). The NHIS collects detailed information on demographic characteristics, health behaviors, and medical conditions through standardized in-person household interviews. Mortality outcomes were obtained through linkage of NHIS participants to the National Death Index (NDI) using established probabilistic matching algorithms developed by NCHS. These linked mortality files provide follow-up for vital status from the date of interview through 31 December 2019.[21]

The 2004 survey cycle included 94,597 participants. After restricting the sample to adults aged ≥ 18 years, 65,715 individuals were eligible for analysis. Additional exclusions were applied for missing information on sleep duration, Charlson Comorbidity Index components, or key covariates required for the fully adjusted models. The final analytic sample comprised 29,997 adults. The NHIS data are publicly available and deidentified. Therefore, this secondary analysis was exempt from institutional review board review at Georgia Southern University and conducted in accordance with the ethical principles of the Declaration of Helsinki.

Outcome assessment

The primary outcome was all-cause mortality. Follow-up time was defined as the interval from the NHIS interview date to the date of death or the end of follow-up (31 December 2019), whichever occurred first. Survival time was measured in months. Participants who remained alive at the end of follow-up were censored at that time.

Exposure assessment: sleep duration

Habitual sleep duration was assessed in the NHIS using the question: *"On average, how many hours of sleep do you get in a 24-hour period?"* Participants reported an integer number of hours. Self-reported sleep duration measures have been widely used in epidemiologic studies and have demonstrated acceptable validity for population-level analyses [6, 7, 31, 32]. Sleep duration was categorized into five groups: 1–4 hours, 5–6 hours, 7–8 hours (reference category), 9 hours, and ≥ 10 hours. These cut-points are consistent with previous epidemiologic studies examining nonlinear or U-shaped associations between sleep duration and mortality [1, 3, 4, 7].

Multimorbidity assessment

Multimorbidity burden was quantified using the Charlson Comorbidity Index (CCI), a validated prognostic index that summarizes comorbidity severity based on weighted chronic conditions associated with mortality risk.[34, 35] The CCI incorporates multiple conditions, including cardiovascular disease, diabetes, chronic pulmonary disease, connective tissue disease, peptic ulcer disease, liver disease, cancer, and other serious illnesses, with each condition assigned a weight reflecting its relative impact on mortality risk. For each participant, a total CCI score was calculated by summing the condition-specific weights.

To characterize gradients in multimorbidity severity, the CCI score was modeled categorically. Participants with a CCI score of 0 were classified as having no multimorbidity. Among individuals with CCI ≥ 1, scores were divided into tertiles based on their distribution in the analytic sample, producing three progressively higher levels of comorbidity burden.

Tertile categorization was used because the distribution of CCI scores in population-based samples is typically right-skewed, with relatively few individuals having very high scores. Grouping CCI values into quantiles improves statistical stability, allows meaningful comparison of risk across levels of disease burden, and has been widely applied in epidemiologic studies examining comorbidity severity and mortality outcomes [34–37].

Covariates

Covariates were selected a priori based on established associations with sleep duration and mortality risk.[1, 3, 6–8, 17, 29, 31] Sociodemographic variables included sex, race/ethnicity, education level, and marital status. Behavioral factors included smoking status (current, former, never), alcohol consumption, physical activity level, and body mass index (BMI) category. All covariates were modeled as categorical variables to reflect clinically meaningful groupings and to maintain comparability with prior NHIS-based epidemiologic analyses.

Statistical analysis

All analyses accounted for the complex sampling design of the NHIS, including sampling weights, primary sampling units (PSUs), and strata, to produce nationally representative estimates. Analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC).

Baseline characteristics were summarized by sleep duration category using weighted descriptive statistics. Continuous variables were summarized using means and standard errors, whereas categorical variables were summarized using weighted percentages.

Survey-weighted Cox proportional hazards regression models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the joint association of sleep duration and multimorbidity with all-cause mortality. Models included sleep duration category, CCI category, and their interaction term to evaluate whether multimorbidity modified the association between sleep duration and mortality.

Two sequential models were fitted. The first model included sleep duration category, CCI category, and their interaction. The second model additionally adjusted for sex, race/ethnicity, education level, marital status, smoking status, alcohol consumption, physical activity, and BMI category. In all analyses, the reference group consisted of participants reporting 7–8 hours of sleep with no multimorbidity (CCI = 0).

Hazard ratios for joint sleep–CCI combinations were estimated using linear combinations of model coefficients derived from the fitted Cox models. Statistical significance was defined using two-sided p-values < 0.05. To evaluate potential reverse causation from underlying illness influencing sleep duration, a sensitivity analysis was conducted excluding participants who died within the first 12 months of follow-up.

Results

Participant characteristics

A total of 28,598 adults were included in the analytic sample. Most participants reported sleeping 7–8 hours per night, which represented the largest sleep category across the population (Table 1). Across the study population, 40.1% (95% CI: 39.4–40.7) had normal body mass index, 35.3% (95% CI: 34.7–35.9) were overweight, and 24.6% (95% CI: 24.0–25.3) were obese. Slightly more than half of participants were female (51.4%, 95% CI: 50.6–52.3), while 48.6% (95% CI: 47.7–49.4) were male.

Most participants identified as White (83.3%, 95% CI: 82.6–84.0), followed by Black/African American (11.4%, 95% CI: 10.8–12.0) and other racial/ethnic groups (5.3%, 95% CI: 5.0–5.7). In terms of education, 59.7% (95% CI: 58.8–60.7) had education beyond high school, whereas 31.9% (95% CI: 31.0–32.7) had completed high school or GED. Regarding health behaviors, 69.0% (95% CI: 68.2–69.7) reported never smoking and 81.0% (95% CI: 80.4–81.7) reported current alcohol use. Approximately half of the population reported never or being unable to perform physical activity (50.3%, 95% CI: 49.3–51.3).

With respect to multimorbidity, 56.6% (95% CI: 55.8–57.4) of participants had no comorbid conditions (CCI = 0), while 34.2% (95% CI: 33.5–34.9) were classified in the first CCI tertile, 7.7% (95% CI: 7.4–8.1) in the second tertile, and 1.4% (95% CI: 1.3–1.6) in the highest tertile. Sleep duration also varied across health profiles. Both very short (1–4 hours) and very long sleep (≥ 10 hours) were more frequently observed among individuals with higher multimorbidity burden and less favorable health behaviors (Table 1). Mean survival time was lowest among individuals reporting ≥ 10 hours of sleep (149.96 months, 95% CI: 145.57–154.35) compared with those reporting 7–8 hours (173.96 months, 95% CI: 173.44–174.48).

Table 1
Baseline Characteristics of Participants by Sleep Duration

Variable	Category	1–4 h, % [95% CI]	5–6 h, % [95% CI]	7–8 h, % [95% CI]	9 h, % [95% CI]	≥ 10 h, % [95% CI]	Total, % [95% CI]
OS Mean		160.94 (157.24–164.65)	173.11 (172.17–174.04)	173.96 (173.44–174.48)	162.52 (159.58–165.46)	149.96 (145.57–154.35)	OS Mean (95% CI)
Body mass index (BMI)	Normal (< 25)	0.7 [0.6; 0.8]	9.5 [9.1; 10.0]	26.3 [25.6; 27.0]	2.0 [1.8; 2.1]	1.6 [1.4; 1.8]	40.1 [39.4; 40.7]
	Overweight (25–29.9)	0.8 [0.6; 0.9]	9.3 [8.9; 9.7]	22.6 [22.0; 23.1]	1.5 [1.3; 1.6]	1.2 [1.1; 1.4]	35.3 [34.7; 35.9]
	Obese (≥ 30)	0.8 [0.7; 0.9]	7.8 [7.5; 8.2]	13.8 [13.3; 14.2]	1.1 [1.0; 1.3]	1.1 [0.9; 1.2]	24.6 [24.0; 25.3]
Sex	Male	45.00 (40.83–49.17)	49.13 (47.82–50.45)	48.57 (47.74–49.41)	41.43 (38.26–44.60)	47.81 (44.18–51.44)	Male % (95% CI)
	Female	55.00 (50.83–59.17)	50.87 (49.55–52.18)	51.43 (50.59–52.26)	58.57 (55.40–61.74)	52.19 (48.56–55.82)	Female % (95% CI)
Race/ethnicity	White only	1.8 [1.6; 1.9]	21.5 [20.8; 22.1]	53.2 [52.5; 54.0]	3.9 [3.6; 4.2]	2.9 [2.7; 3.1]	83.3 [82.6; 84.0]
	Black/African American only	0.4 [0.3; 0.5]	3.5 [3.3; 3.8]	6.3 [5.8; 6.7]	0.5 [0.4; 0.6]	0.8 [0.6; 0.9]	11.4 [10.8; 12.0]
	Other	0.2 [0.1; 0.2]	1.6 [1.4; 1.8]	3.2 [2.9; 3.5]	0.2 [0.2; 0.3]	0.2 [0.1; 0.3]	5.3 [5.0; 5.7]
Education	< High school	0.3 [0.3; 0.4]	2.0 [1.8; 2.2]	4.9 [4.6; 5.2]	0.5 [0.4; 0.6]	0.6 [0.5; 0.7]	8.4 [7.9; 8.9]
	High school / GED	0.8 [0.7; 0.9]	8.4 [7.9; 8.8]	19.6 [18.9; 20.2]	1.6 [1.4; 1.8]	1.5 [1.3; 1.7]	31.9 [31.0; 32.7]
	> High school	1.1 [0.9; 1.2]	16.2 [15.6; 16.8]	38.7 [37.9; 39.5]	2.4 [2.1; 2.6]	1.4 [1.2; 1.6]	59.7 [58.8; 60.7]
Marital status	Married	1.1 [1.0; 1.3]	15.1 [14.6; 15.7]	37.8 [37.1; 38.6]	2.4 [2.2; 2.6]	1.7 [1.5; 1.9]	58.2 [57.5; 59.0]
	Separated/divorced/ Widowed	0.7 [0.6; 0.8]	5.7 [5.4; 6.0]	10.2 [9.9; 10.6]	0.9 [0.8; 1.0]	0.9 [0.8; 1.0]	18.4 [17.9; 18.9]

Variable	Category	1–4 h, % [95% CI]	5–6 h, % [95% CI]	7–8 h, % [95% CI]	9 h, % [95% CI]	≥ 10 h, % [95% CI]	Total, % [95% CI]
	Single/never Married	0.5 [0.4; 0.6]	5.7 [5.3; 6.0]	14.7 [14.1; 15.3]	1.2 [1.1; 1.4]	1.2 [1.1; 1.4]	23.3 [22.6; 24.1]
Smoking status	Current smoker	0.2 [0.1; 0.2]	1.5 [1.4; 1.7]	2.7 [2.4; 2.9]	0.3 [0.2; 0.4]	0.2 [0.2; 0.3]	4.9 [4.6; 5.2]
	Former smoker	0.6 [0.5; 0.7]	6.8 [6.4; 7.1]	16.4 [15.8; 17.0]	1.3 [1.1; 1.4]	1.1 [1.0; 1.3]	26.1 [25.4; 26.8]
	Never smoker	1.2 [1.0; 1.4]	17.6 [17.0; 18.2]	44.9 [44.1; 45.7]	3.0 [2.8; 3.3]	2.2 [2.0; 2.5]	69.0 [68.2; 69.7]
Alcohol use	Former drinker	0.7 [0.6; 0.8]	5.7 [5.4; 6.1]	10.5 [9.9; 11.0]	1.0 [0.8; 1.1]	1.1 [0.9; 1.3]	19.0 [18.3; 19.6]
	Current drinker	1.7 [1.4; 1.9]	22.2 [21.5; 22.9]	51.6 [50.8; 52.5]	3.2 [2.9; 3.4]	2.4 [2.2; 2.7]	81.0 [80.4; 81.7]
Physical activity	Never/unable	1.4 [1.2; 1.6]	13.3 [12.8; 13.8]	30.9 [30.1; 31.8]	2.4 [2.1; 2.6]	2.4 [2.1; 2.6]	50.3 [49.3; 51.3]
	Light/moderate	0.8 [0.7; 0.9]	13.2 [12.6; 13.7]	32.1 [31.3; 33.0]	2.2 [2.0; 2.4]	1.4 [1.2; 1.5]	49.7 [48.7; 50.7]
Charlson comorbidity index (CCI)	0 (none)	0.7 [0.6; 0.8]	14.3 [13.7; 14.8]	37.5 [36.7; 38.3]	2.3 [2.1; 2.5]	1.9 [1.6; 2.1]	56.6 [55.8; 57.4]
	Tertile 1	1.0 [0.9; 1.2]	9.7 [9.3; 10.1]	20.6 [20.0; 21.2]	1.6 [1.4; 1.7]	1.3 [1.2; 1.5]	34.2 [33.5; 34.9]
	Tertile 2	0.5 [0.4; 0.5]	2.2 [2.0; 2.4]	4.0 [3.8; 4.3]	0.6 [0.5; 0.7]	0.5 [0.4; 0.5]	7.7 [7.4; 8.1]
	Tertile 3	0.1 [0.1; 0.2]	0.4 [0.3; 0.5]	0.6 [0.5; 0.7]	0.1 [0.1; 0.2]	0.2 [0.1; 0.3]	1.4 [1.3; 1.6]

Percentages represent column percentages based on total participants within each sleep-duration category (1–4 h: 783; 5–6 h: 8098; 7–8 h: 18,609; 9 h: 1343; ≥10 h: 1164).

Joint association between sleep duration, multimorbidity, and mortality

Table 2 presents the joint association between sleep duration and multimorbidity burden with all-cause mortality. In crude models, both short and long sleep durations were associated with higher mortality compared with the reference category of 7–8 hours, and mortality risk increased progressively with higher levels of multimorbidity.

Among individuals without multimorbidity (CCI = 0), sleeping 1–4 hours were associated with increased mortality risk (HR 2.08, 95% CI: 1.11–3.89) relative to the reference group. Similar patterns were observed for long sleep, with individuals reporting ≥ 10 hours experiencing higher mortality (HR 2.14, 95% CI: 1.60–2.88).

Across increasing multimorbidity tertiles, mortality risk rose substantially. For example, individuals sleeping ≥ 10 hours in the highest multimorbidity category had markedly elevated risk (crude HR 34.22, 95% CI: 23.70–49.42) compared with the reference group.

After adjustment for sociodemographic and behavioral factors, effect estimates were attenuated but the overall pattern remained. In the fully adjusted model, participants reporting ≥ 10 hours of sleep in the highest CCI tertile had significantly higher mortality risk (adjusted HR 11.15, 95% CI: 6.54–19.01) relative to the reference group. Similar elevated risks were observed for 9 hours of sleep in the highest multimorbidity category (HR 6.83, 95% CI: 3.89–12.02). Overall, mortality risk increased in a graded manner with increasing multimorbidity burden across sleep categories.

Table 2

Table 2. Crude and adjusted analyses of Cox regression between sleep duration and multimorbidity burden for all-cause mortality in US adults (N = 28,598). NHIS–NDI Linked Mortality Files, United States, 2004–2019.

Sleep duration	CCI = 0 (none)		CCI Tertile 1		CCI Tertile 2		CCI Tertile 3	
	Crude HR (95% CI)	Adjusted HR (95% CI)	Crude HR (95% CI)	Adjusted HR (95% CI)	Crude HR (95% CI)	Adjusted HR (95% CI)	Crude HR (95% CI)	Adjusted HR (95% CI)
1–4 h	**2.08 (1.11–3.89)**	1.43 (0.55–3.68)	**6.83 (3.59–13.01)**	2.61 (0.98–6.98)	**19.07 (9.98–36.45)**	**4.16 (1.58–11.00)**	**33.23 (16.87–65.46)**	**6.12 (2.17–17.23)**
5–6 h	1.06 (0.90–1.25)	1.02 (0.80–1.30)	**3.48 (2.80–4.33)**	**1.87 (1.33–2.63)**	**9.72 (7.72–12.23)**	**2.99 (2.10–4.27)**	**16.94 (12.63–22.71)**	**4.39 (2.75–7.01)**
7–8 h	**1.00 (Ref)**	**1.00 (Ref)**	**3.28 (2.97–3.62)**	**1.83 (1.56–2.15)**	**9.16 (8.15–10.30)**	**2.92 (2.41–3.55)**	**15.96 (12.99–19.61)**	**4.29 (3.03–6.09)**
9 h	**1.52 (1.18–1.96)**	**1.59 (1.05–2.42)**	**4.99 (3.77–6.59)**	**2.91 (1.82–4.68)**	**13.92 (10.43–18.59)**	**4.65 (2.89–7.50)**	**24.26 (17.31–34.01)**	**6.83 (3.89–12.02)**
≥ 10 h	**2.14 (1.60–2.88)**	**2.60 (1.79–3.78)**	**7.03 (5.10–9.70)**	**4.76 (3.06–7.38)**	**19.64 (14.00–27.54)**	**7.59 (4.85–11.89)**	**34.22 (23.70–49.42)**	**11.15 (6.54–19.01)**

In bold: statistically significant association. # adjusted for sex, race/ethnicity, education level, marital status, smoking status, alcohol consumption, physical activity, and body mass index (BMI); HR: odds ratio; 95% CI: 95% confidence interval.

Sensitivity analysis

In sensitivity analyses excluding deaths occurring within the first 12 months of follow-up, the overall pattern remained consistent (Table 3). Long sleep duration remained strongly associated with mortality across multimorbidity levels. Individuals reporting ≥ 10 hours of sleep in the highest CCI category had markedly elevated mortality risk (HR 33.30, 95% CI: 14.87–74.64) compared with the reference group.

Table 3
Sensitivity analysis of Cox regression between sleep duration and multimorbidity burden for all-cause mortality after excluding deaths within the first 12 months of follow-up.

Sleep duration	CCI = 0	CCI 1–2	CCI 3–4	CCI ≥ 5
1–4 h	1.61 (0.62–4.19)	3.40 (1.30–8.87)	3.55 (1.19–10.61)	9.14 (2.58–32.41)
5–6 h	0.94 (0.73–1.19)	2.54 (1.80–3.58)	5.54 (3.79–8.09)	14.13 (7.84–25.46)
7–8 h	1.00 (Ref)	3.39 (2.89–3.96)	7.63 (6.29–9.26)	13.19 (9.56–18.20)
9 h	1.59 (1.01–2.49)	5.35 (3.22–8.87)	11.27 (6.55–19.39)	26.26 (12.36–55.81)
≥ 10 h	2.49 (1.55–4.00)	7.81 (4.50–13.55)	12.00 (6.60–21.82)	33.30 (14.87–74.64)
Reference group: 7–8 hours' sleep and CCI = 0				

Discussion

The present study examined the joint association of sleep duration and multimorbidity burden with all-cause mortality in a nationally representative sample of US adults. We observed a clear gradient in mortality risk across multimorbidity levels within every sleep-duration category, with the highest risks consistently occurring among adults reporting longer sleep durations in the presence of greater comorbidity burden. In crude analyses, both short and long sleep were associated with elevated mortality compared with 7–8 hours, and these associations strengthened markedly as multimorbidity increased. After adjustment for sociodemographic and behavioral covariates, estimates for short sleep were attenuated, whereas long sleep remained consistently associated with higher mortality across multimorbidity strata.

Our findings are consistent with the broader literature describing U- or J-shaped associations between sleep duration and mortality, with long sleep often demonstrating the most stable association after confounding control. [1, 3, 4, 6, 7, 16, 31] What this study adds is evidence that the sleep–mortality relationship should not be interpreted in isolation from multimorbidity severity. Using a validated comorbidity index to characterize multimorbidity burden, we found that mortality hazards increased in a graded fashion across higher levels of multimorbidity for each sleep category, including the reference sleep group. This pattern suggests that multimorbidity is not simply a covariate to "adjust away," but a meaningful context that amplifies vulnerability and clarifies which sleep groups carry the greatest risk.

Several mechanisms may help explain why prolonged sleep showed the strongest and most consistent association with mortality, particularly among adults with higher comorbidity burden. Prolonged sleep has been linked to systemic inflammation, immune dysregulation, endocrine and metabolic disturbances, depressive symptoms, frailty, and subclinical or undiagnosed disease processes [10–12, 16, 19, 20, 22, 24–26, 29]. These pathways overlap with the biological dysregulation underlying multimorbidity and may reflect reduced physiologic reserve in individuals with multiple chronic conditions [24–26, 29]. In this context, long sleep may function less as a causal exposure and more as a marker of underlying disease severity, functional impairment, or prodromal illness [10–12, 16]. That interpretation is consistent with the strong joint risks we observed for long sleep in the highest multimorbidity strata.

The attenuation of short-sleep estimates after adjustment is also informative. Short sleep is socially patterned and often clusters with socioeconomic stress, occupational constraints such as shift work, caregiving demands, and

other behavioral risk factors [3, 27, 31]. These correlated factors can inflate crude sleep–mortality associations, and adjustment for key demographic and behavioral characteristics may reduce the portion of risk attributable to sleep duration alone. In our study, the persistence of risk for long sleep after adjustment, alongside the weakening of short-sleep associations, supports prior work suggesting that long sleep may better capture underlying health burden and preclinical disease processes than short sleep in population-based cohorts [10, 16, 19, 20, 29, 32].

Because reverse causation is a common concern in sleep epidemiology [34, 35], we conducted a sensitivity analysis excluding deaths occurring within the first 12 months of follow-up. The overall pattern of results remained similar, with long sleep continuing to show elevated mortality hazards across multimorbidity strata. This strengthens the inference that the observed joint association is not explained solely by severe illness immediately preceding death, although some degree of reverse causation cannot be fully excluded given that sleep duration and comorbidity were assessed at baseline only.

These findings have practical implications. In clinical and public health settings, sleep duration may provide useful risk information when interpreted alongside multimorbidity burden. Very long sleep in adults with multiple chronic conditions may warrant closer evaluation for disease progression, functional decline, depressive symptoms, cognitive impairment, or sleep-disordered breathing. At the same time, the graded risk pattern across multimorbidity levels underscores the importance of integrated chronic disease management, where sleep assessment is considered part of a broader risk profile rather than a standalone exposure.

This study has limitations. Sleep duration and chronic conditions were self-reported and may be misclassified. The NHIS did not include objective sleep measures or detailed sleep quality indicators such as insomnia severity, sleep fragmentation, or sleep apnea, limiting mechanistic interpretation. In addition, sleep duration and multimorbidity were assessed at baseline, and changes over time were not captured; thus, time-varying confounding and disease progression may influence associations. Although we adjusted for key sociodemographic and behavioral factors and accounted for the complex survey design, residual confounding remains possible. Strengths of this study include the use of a large, nationally representative cohort with long-term mortality linkage, the use of a validated comorbidity severity measure to define multimorbidity, and survey-weighted survival modeling that supports generalizability to the US adult population.

Conclusions

In this nationally representative cohort of US adults, sleep duration and multimorbidity burden were jointly associated with all-cause mortality. Mortality risk increased progressively with higher multimorbidity across all sleep categories, with the highest risks observed among individuals reporting prolonged sleep and greater comorbidity burden. After adjustment for sociodemographic and behavioral factors, long sleep remained a consistent predictor of mortality, whereas associations with short sleep were attenuated. These findings suggest that prolonged sleep may serve as a marker of underlying health vulnerability, particularly among individuals with multiple chronic conditions. Considering multimorbidity alongside sleep duration may improve risk identification and inform clinical and public health strategies aimed at reducing mortality.

Declarations

Ethics approval and consent to participate

This study used publicly available, de-identified data from the 2004 National Health Interview Survey (NHIS) and its linked mortality files provided by the National Center for Health Statistics (NCHS). Because the data are publicly available and contain no identifiable information, institutional review board approval and informed consent were not required for this secondary analysis. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The data used in this study are publicly available from the National Health Interview Survey (NHIS) and the Linked Mortality Files provided by the US National Center for Health Statistics (NCHS). Data can be accessed through the NCHS Research Data Center or downloaded from the NHIS website:
https://www.cdc.gov/nchs/nhis/

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

E.U.A. led the conceptualization of the study, data curation, formal statistical analysis, and drafting of the manuscript. T.V.A., T.K., H.S., and L.Y. contributed to the study design, interpretation of results, and critical revision of the manuscript for important intellectual content. H.S. and L.Y. provided methodological supervision and oversight of the analytical procedures. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Authors' information (optional)

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