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ORIGINAL ARTICLE

Association of sleep duration and all-cause and cancer-specific mortality: results of 2004 national health interview survey (NHIS)

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Abstract

Epidemiologic research has demonstrated a connection between the duration of sleep and the risk of overall mortality. This research investigates the correlation between sleep duration (SD) and the likelihood of all-cause and cancer-specific mortality among cancer patients, exploring the association between SD and mortality risk. The study used the National Health Interview Survey (NHIS) data from 2004, a U.S.-based survey linked to a mortality database up to December 31, 2019. A total of 26,976 participants based on cancer responses, including 2082 cancer patients and 24,894 non-cancer patients, were included in this study. Participants self-reported SD (categorized as ≤ 5, 6, 7, 8, 9, or ≥ 10 h/day) was used. The Cox proportional hazards model for mortality risk was performed with demographic adjustments. Mortality risk was higher in adults with and without cancer and extremes (insufficient or more than sufficient) of SD. A J-shaped association was found between SD and all-cause and cancer-specific mortality risk among cancer and non-cancer patients. Among the cancer patients, compared with the reference group (7 h/day), both shorter and longer SDs were associated with increased risk of all-cause and cancer-specific mortality (≤ 5 h/day, HR 1.48 CI [1.77, 1.88]; 8 h/day, HR 1.45 CI [1.23, 1.72]; 9 h/day, HR 1.53 CI [1.18,1.99], ≥ 10 h/day, HR 2.15 CI [1.66, 2.78]); except the SD 6 h/day, HR 1.14 CI [0.93, 1.40]. The analysis included 349,936 person-years of observation. This study suggests that sleeping too long and too short is associated with increased risk among patients with all-cause and cancer-specific mortality

Keywords Sleep duration · Hazard ratio · Mortality · Confidence interval

Introduction

Sleep duration (SD) is increasingly recognized as a significant modifiable risk factor to influence both morbidity and mortality [1]. Therefore, there is an increasing focus on investigating the potential effects of sleep duration on different facets of health. Inadequate sleeping hours are a significant concern for individuals with cancer, and it is essential to incorporate the assessment and management of sleep issues into palliative care [2]. Although the association between SD and all-cause mortality has been investigated in several studies among the general population [3], few studies have explored this association between SD and all-cause cancer and cancer-specific mortality [4–6]. For instance,

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in a study among lung cancer patients, Dean and his colleagues found a strong correlation between SD and cancer mortality [7]. On average, it has been reported that for individuals battling with breast cancer, their average SD ranges between 4.8 to 7 h per night with sleep latency between 21 to 55 min [8, 9], whereas the National Institutes of Health (NIH) (https://www.nhlbri.nih.gov/health/sleep/how-much-sleep) recommends 7–9 h of sleep per day for healthy adults [10]. Lehrer and colleagues discovered increased all-cause cancer mortality in individuals reporting insufficient sleep ($p = 0.017$) in a study that covered 50 US states and the District of Columbia [11]. Thompson and his team found that shorter SD is associated with higher genetic-based recurrence scores for tumor aggressiveness among breast cancer patients [12]. In a study among lung cancer patients, Wong and his colleagues also claimed significantly increased hazard ratios (HR) with increased mortality among 42,422 Chinese farmers with inadequate SD [13]. A prospective study on 292 advanced hepatobiliary-pancreatic cancer patients suggested that SD is associated with survival in the patients [14]. However, the findings regarding the influence of SD on overall cancer mortality have shown varying degrees of consistency in the available literature [15–17]. This suggests that further research can advance our scientific understanding of the potential interrelationships between SD and cancer mortality and propose interventions to help achieve optimal sleeping hours, adding significant information to the growing body of research. To investigate further, we used the National Health Interview Survey (NHIS-2004), a U.S.-based database, which is considered nationally representative for a valid comparison among groups and justifies generalizability, notably, integrating all-cause cancer patients. Therefore, the proposed study aimed to investigate how the amount of sleep someone gets might affect all-cause and cancer-specific mortality after adjusting for sociodemographic and disease-related factors.

Materials and methods

Data source

The NHIS is an annual cross-sectional and multistage survey conducted by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC). The NHIS uses a stratified, multistage probability design to select participants and generates a representative sample of the US civilian, non-institutionalized population. Information on health status and lifestyle behaviors is collected from all family members; additional information is collected from one randomly selected sampled child and one adult from each family. A distinctive feature of the NHIS 2004 dataset is its meticulous documentation of sleep-related parameters, thereby rendering it an invaluable resource for investigations into sleep health and its implications. More details of the NHIS survey design, methodology, protocols, and weighting can be found on the NHIS website (https://www.cdc.gov/nchs/nhis/index.htm). The NHIS is a publicly available data repository and is considered exempt under the ethical board review of the corresponding author's institution.

Study participants

A total of 94,597 adults participated in the 2004 NHIS survey (https://ftp.cdc.gov/pub/Health_Statistics/NCHS / Datasets/NHIS/2004). The current analysis used data from the NHIS Public-Use Person File, NHIS Family File, NHIS Household File, and NHIS Sample Adult File, including data on prior cancer diagnoses of all cancer types e.g. blood cancer, skin cancer, bone cancer, bladder cancer, prostate cancer, uterine cancer, breast cancer, etc. (https://ftp.cdc.gov/pub/Health_Statistics/NCHS/ Program_Code/NHIS/2004/sampleadult/samadult_summary.pdf), time since diagnosis, and sociodemographic characteristics. The 2004 NHIS data is linked to the mortality database up to Dec 31, 2019. We set a criterion for inclusion and exclusion (Fig. 1) where participants who did not respond to the question 'Ever told by a doctor you had cancer' were excluded, which resulted in 31,331 participants. Subsequently, all responses marked as missing, unknown, refused, and not ascertained were removed. After applying the exclusion criteria (Fig. 1), a total of 26,976 (male, $n = 12,133$ and female, $n = 14,843$) participants' data remained to analyze, where we had 2082 observations with cancer (Participants' self-report) and 24,894 observations without cancer. Using descriptive statistics and other statistical tests (e.g., chi-square tests for categorical variables and t-tests for continuous variables), the analysis demonstrated that the remaining participants are representative of the overall study population, and the exclusion did not introduce significant bias.

Study exposure: sleep duration

The survey obtained SD data from a self-reported question, 'On average, how many hours of sleep do you get in a 24-h period?' with answers given in whole hours. In this study, the participant responses were categorized into six SD categories (≤ 5 h, 6 h, 7 h, 8 h, 9 h, and ≥ 10 h). The study considered two ends of the sleep spectrum: one end included participants who slept 5 h or less (considered insufficient sleep) [15, 19], while the other end consisted of participants who slept 10 h or more (considered excessive sleep) [19]. Among the total participants of 26,976 adults, a total count of 2281 (8.46%) slept for 5 h or less, and a total count of 1106 (4.10%) slept for 10 h or more. A total count of 210

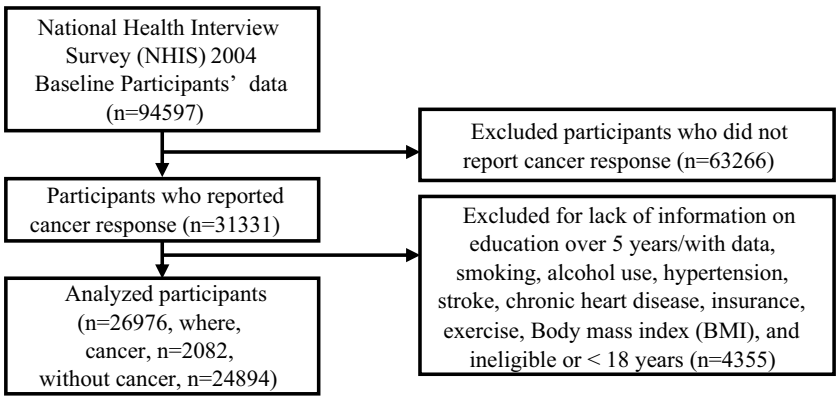

Fig. 1 Participant inclusion criteria from the National Health Interview Survey (NHIS)

of the participants (10.09%) slept for 5 h or less, and a total count of 122 of the participants (5.86%) slept for 10 h or more among the cancer patients (Table 1). Following previous studies, we set the reference category for sleep duration to 7 h [18, 19].

Study outcome: mortality

The mortality status of participants in the NHIS 2004 dataset was determined by employing a probabilistic approach to match their records with the National Death Index (NDI) through 31 December 2019. This method enabled the identification of participants who had passed away. Thus, follow-up time is defined as the time from interview to death for the deceased and from interview to 31 December 2019 for survivors. The total person-years of follow-up in this analysis is 349,936 person-years. NHIS public use ID (public-use Linked Mortality Files (LMFs) was used to link NHIS and NDI and the Data Linkage Program linked to vital and other administrative data. The causes of death were systematically coded and categorized following the International Classification of Diseases (ICD-10) revision guidelines. In this study, the focus was on assessing all-cause and cancer-specific mortality. It is worth noting that previous research has established the accuracy of death information obtained from the NDI records, with the matching method demonstrating a high level of agreement [18].

Study covariates

Demographic variables were age (< 50 years / > 50 years), sex (male/female), race/ethnicity (Hispanic, non-Hispanic white, and others), and levels of education (less than high school degree, high school degree, and more than high school degree). Lifestyle factors were body mass index (BMI) which was categorized into three types (low BMI [< 18.5 kg/m^2], medium BMI [18.5–24.9 kg/m^2] and high BMI [> 25 kg/m^2]), smoking status (non-smoker, current smoker, former smoker), alcohol use (lifetime abstainer, current drinker, former drinker), and physical activity (light/moderate physical activity, never/unable to do light or moderate physical activity). Chronic conditions referred to self-reported diagnoses of hypertension (yes/no), coronary heart disease (yes/no), and stroke (yes/no). Additionally, various types of insurance coverage were incorporated into the analysis.

Statistical analysis

We conducted descriptive statistics on the participants with cancer to present the distribution of participants' baseline characteristics based on their SD. Continuous variables, such as age, were expressed as mean ± standard error (SE), while categorical variables were presented as frequency and percentages (%). Continuous variables were later converted into ordinal categorical variables. To compare the baseline characteristics, including both the exposure variable (sleep duration) and covariates, we employed Pearson's chi-squared ($\chi 2$) tests. To assess the proportional hazards assumption, graphical log–log plots were used, which were found to be met in each model. Person-years were calculated from the recruitment date to the end date of the follow-up or censoring date. We employed multivariate Cox proportional hazards regression model to estimate and compare the HR along with the corresponding 95% confidence intervals (CIs) among cancer and non-cancer participants to examine the association between SD categories and all-cause mortality. We compared the mortality risk in different SD categories using one unadjusted and three adjusted models. The reference group for SD was set at 7 h per day. In the Adjusted Model-1 of Table 2, we made adjustments for age (reference- < 50 years), and sex, with male as the reference category; in Adjusted Model-2, we adjusted for sex (reference-male), age (reference- < 50 years), BMI (reference-medium BMI), race (reference-non-Hispanic white), smoking status (reference-never), alcohol consumption status (reference-never), physical activity (reference-light/moderate), education status (reference-high school degree), hypertension

Table 1 Baseline characteristics among cancer patients according to sleep duration

Characteristic	Sleep duration (hours/day)						p-value
	≤5 h	6 h	7 h	8 h	9 h	≥10 h	
Sample size, n (%)	210 (10.09)	383 (18.40)	544 (26.13)	686 (32.95)	137 (6.58)	122 (5.86)	< 0.001
Age, Mean (SE)	61.5 (17.6)	61.25 (15.6)	61.45 (15.02)	65.66 (14.95)	66.35 (15.87)	70.57 (13.90)	< 0.001
Sex, n (%)							
Male	72 (8.64)	148 (17.77)	210 (25.60)	300 (36.73)	49 (5.77)	54 (6.26)	0.08
Female	138 (11.71)	235 (18.36)	334 (26.40)	386 (30.27)	88 (7.23)	68 (5.74)	
BMI, n (%)							
Low	15 (15.56)	28 (8.11)	19 (20.39)	14 (21.28)	16 (12.45)	17 (15.41)	0.05
Medium	140 (12.14)	232 (22.89)	402 (27.61)	523 (28.72)	86 (6.55)	75 (8.59)	
High	57 (11.47)	103 (20.72)	123 (24.75)	149 (29.98)	35 (7.04)	30 (6.04)	
Race, n (%)							
Hispanic	16 (12.62)	29 (21.57)	34 (25.25)	40 (30.83)	11 (5.11)	10 (5.74)	0.11
Non-Hispanic white	169 (9.48)	317 (18.77)	470 (26.40)	576 (33.97)	113 (6.86)	90 (5.05)	
Non-Hispanic other	25 (11.90)	37 (18.66)	40 (19.35)	70 (34.20)	11(5.03)	21 (10.21)	
Education Level, n (%)							
Less than a high school degree	58 (14.62)	72 (18.80)	75 (17.79)	131 (32.10)	36 (8.28)	35 (8.69)	< 0.001
High school degree	58 (9.62)	113 (18.50)	144 (24.47)	205 (34.88)	40 (6.20)	38 (6.15)	
More than a high school degree	94 (8.76)	198 (18.70)	325 (30.74)	350 (32.02)	61 (5.53)	49 (4.16)	
Smoking status, n (%)							
Current	53 (15.24)	64 (18.71)	89 (25.36)	104 (29.16)	24 (6.52)	16 (4.11)	0.002
Previous	65 (8.95)	145 (18.86)	192 (24.29)	266 (33.78)	68 (8.64)	53 (6.44)	
Never	92 (9.81)	174 (18.43)	263 (27.35)	316 (33.06)	45 (4.85)	53 (5.44)	
Alcohol drinking status, n (%)							
Current	103 (9.05)	208 (18.31)	343 (30.05)	353 (31.46)	57 (5.61)	47 (4.52)	< 0.001
Previous	59 (11.10)	95 (18.80)	94 (17.28)	175 (34.51)	42 (8.66)	48 (9.34)	
Never	48 (10.86)	80 (17.89)	107 (23.67)	158 (34.03)	38 (8.74)	27 (5.13)	
Physical activity status, n (%)							
Never/Unable to do	122 (11.10)	193 (18.39)	217 (20.89)	357 (34.04)	74 (7.01)	86 (8.49)	< 0.001
Light/Moderate	88 (8.90)	190 (18.61)	327 (31.11)	329 (31.96)	63 (6.99)	36 (3.51)	
Hypertension status, n (%)							
Yes	112 (10.33)	185 (18.30)	236 (23.38)	349 (34.87)	72 (7.55)	68 (6.64)	0.02
No	98 (9.67)	198 (18.70)	308 (29.62)	337 (31.13)	65 (6.45)	54 (5.26)	
CHD status, n (%)							
Yes	27 (11.86)	44 (17.49)	47 (19.64)	82 (33.95)	19 (7.87)	26 (10.31)	0.005
No	183 (9.14)	339 (18.51)	497 (27.36)	604 (32.05)	118 (6.13)	96 (5.69)	
Stroke, n (%)							
Yes	20 (13.52)	25 (17.53)	19 (13.49)	43 (29.27)	14 (9.22)	24 (16.67)	< 0.001
No	190 (9.48)	358 (18.47)	525 (27.51)	643 (33.73)	123 (6.78)	98 (5.33)	
Insurance type, n (%)							
Medicare or Medicaid	122 (10.10)	202 (16.74)	262 (21.16)	420 (35.22)	95 (7.87)	91 (7.59)	< 0.001
Private	56 (7.67)	140 (19.55)	245 (34.04)	213 (31.05)	32 (4.36)	19 (2.57)	
Others	32 (17.24)	41 (22.70)	37 (20.80)	53 (27.73)	14 (7.22)	8 (4.56)	

h hours, *n* number of participants, *SE* Standard error, *CHD* Coronary heart disease, *BMI* Body mass index

status (reference-no), stroke status (reference-no), and CHD status (reference-no). The Adjusted Model-3 was adjusted for the significant variables, sex, age, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status, history of disease status (reference-no history), and insurance type (reference- Medicaid/Medicare). We employed the stepwise regression (forward selection and backward elimination) method for potential predictors. Subgroup analysis was done for age and sex categories to examine

Table 2 Sleep duration and the risk of mortality stratified by the presence of cancer

SD (h/day)	Participants, n	Deaths, n	Unadjusted model[a]		Adjusted model 1[b]		Adjusted model 2[c]		Adjusted model 3[d]	
			HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value
No Cancer	24,894	4205								
≤ 5 h	2071	442	1.81(1.64,2.06)	< .0001	1.67 (1.49, 1.88)	< .0001	1.36 (1.20,1.52)	< .0001	1.35 (1.20,1.52)	< .0001
6 h	5315	778	1.21 (1.09,1.33)	< 0.0001	1.21 (1.10,1.33)	< .0001	1.13 (1.03,1.24)	0.01	1.13 (1.03, 1.25)	0.01
7 h	7475	921	1 (reference)	–	1 (reference)	–	1 (reference)	–	1 (reference)	–
8 h	7920	1385	1.46 (1.35,1.59)	< 0.0001	1.26 (1.16,1.37)	< .0001	1.21 (1.11,1.32)	< .0001	1.21 (1.12, 1.32)	< .0001
9 h	1129	302	2.39 (1.64,2.06)	< 0.0001	1.82 (1.64,2.13)	< .0001	1.64 (1.44,1.87)	< .0001	1.65 (1.44, 1.88)	< .0001
≥ 10 h	984	377	3.79 (3.36,4.27)	< 0.0001	2.79 (2.47,3.15)	< .0001	2.13 (1.88,2.41)	< .0001	2.14 (1.89, 2.42)	< .0001
Cancer	2082	1001								
≤ 5 h	210	101	1.43 (1.13,1.8)	0.002	1.48 (1.17,1.88)	0.001	1.23 (0.96,1.57)	0.08	1.25 (0.98, 1.59)	0.06
6 h	383	157	1.11 (0.90,1.37)	0.29	1.14 (0.92,1.40)	0.21	1.04 (0.84,1.28)	0.70	1.04 (0.84,1.28)	0.69
7 h	544	204	1 (reference)	–	1 (reference)	–	1 (reference)	–	1 (reference)	–
8 h	686	378	1.68 (1.42,2.00)	< 0.0001	1.45 (1.22,1.72)	< .0001	1.36 (1.14,1.61)	0.0005	1.15 (1.03, 1.40)	0.001
9 h	137	77	1.81 (1.39,2.36)	< 0.0001	1.53 (1.17,1.99)	0.001	1.25 (0.96,1.57)	0.10	1.36 (1.04, 1.64)	0.08
≥ 10 h	122	84	2.94 (2.21,3.79)	< 0.0001	2.15 (1.66,2.77)	< .0001	1.66 (1.27,2.15)	0.0001	1.66 (1.28, 2.15)	0.06

[a] Unadjusted Model: not adjusted for any covariate

[b] Adjusted Model 1: Adjusted for age, sex

[c] Adjusted Model 2: Adjusted for sex, age, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status

[d] Adjusted Model 3: Adjusted for sex, age, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status, history of disease status, insurance type

SD Sleep duration, *HR* Hazard ratio, *CI* Confidence interval, *BMI* Body mass index, *CHD* Coronary heart disease

the association between SD categories and all-cause mortality on the observations which is presented in Table 3 and Table 4. A p-value < 0.05 was considered statistically significant. All data analyses were performed using SAS version 9.4 and Rstudio version 4.3.1.

Results

Participants' characteristics

A comprehensive count of 1001 deaths (523 among women and 478 among men) was documented within the subset of 2082 participants diagnosed with cancer. In contrast, among 24,894 adults without cancer, there were 4205 recorded deaths (2216 among women and 1989 among men) over the follow-up period. The baseline characteristics of participants with cancer are presented in Table 1. The relationship between SD and the risk of mortality is shown in Table 2, with a distinction made between participants who had received a cancer diagnosis and those who had not. Table 3 and Table 4 show the relationship between SD and mortality hazards within the sample stratified by sex and age, respectively. The sample includes 12,133 males and 14,843 females, and 15,751 participants under 50 years old, and 10,737 participants over 50 years old.

Impact of sleep duration on mortality

Table 2 provides a clear insight into the relationship between SD and mortality. Notably, the data reveals a positive association between extreme SDs, either too little or too much sleep, and the mortality risk for individuals with and without cancer. Participants with cancer, who slept ≤ 5 h/day, 6 h/day, 8 h/day, and 9 h/day faced elevated cancer mortality risks of 43%, 11%, 68%, and 81%, respectively, with this risk surpassing twofold for cancer patients who slept ≥ 10 h/day. It is worth noting, the association between SD and cancer mortality risk displayed statistical significance ($p < 0.001$) for those who slept 9 h/day (HR 1.81 [1.39, 2.36]), 8 h/day (HR 1.68 [1.42, 2.00]), and ≥ 10 h/day (HR 2.94 [2.28, 3.79]) within the unadjusted model. A similar pattern is observed within the Unadjusted model for non-cancer observations with p-values of the HR being significant for all SD categories.

After accounting for age and sex adjustments in Adjusted Model 1, a distinct pattern emerges. Among individuals without cancer, those who slept for ≤ 5 h/day, 6 h/day, 8 h/day, 9 h/day and > 10 h/day faced increased mortality risks of 67% (HR 1.67 [1.49, 1.88]), 21% (HR 1.21 [1.10,1.33]), 26% (HR 1.26 [1.16,1.37]), 87% (HR 1.87 [1.64,2.13]), and 179% (HR 2.79 [2.47,3,15]) respectively, compared to those who slept 7 h/day (as seen in Table 2). It is worth emphasizing that the associations found between SD and mortality risk among participants without cancer also emerged as statistically significant (P-value < 0.05) in this model. For individuals with cancer within the same model, the mortality risk rose by 48% (HR 1.48 [1.17,1.88]), 45% (HR 1.45 [1.22,1.72]), 53% (HR 1.53 [1.17,1.99]), and 115% (HR 2.15 [1.66, 2.77]) for those who slept ≤ 5 h/day, 8 h/day, 9 h/day, and > 10 h/day respectively, with significant p-values.

Interestingly, the risk of mortality was consistently higher for individuals who slept either less than or more than the recommended sleeping hours of 7–9 h, as outlined by the National Institutes of Health (www.nhlbi.nih.gov/health/health-topics/topics/sdd/howmuch.html), even after adjusting for more variables. In Adjusted Model 2, after adjusting for selected variables, mortality risk remained increased for non-cancer participants with a significant p-value of < 0.05 for all the SD categories compared to the reference category of 7 h/day. Whereas, for cancer patients in this model, those who slept for 8 h/day and > 10 h/day, the increased risk for mortality was found statistically significant, and those who slept for ≤ 5 h/day showed an increased HR of 1.23 with a p-value of 0.08.

We further adjusted the model with significant variables (Adjusted model 3), as shown in Table 2. Individuals without cancer who slept ≤ 5 h/day, 6 h/day, 8 h/day, and 9 h/day faced elevated cancer mortality risks of 35% (HR 1.35 [1.20,1.52]), 13% (HR 1.13 [1.03, 1.25]), 21% (HR 1.21 [1.12, 1.32]), and 64% (HR 1.65 [1.44, 1.88]), respectively, in comparison to those who slept 7 h/day. Notably, the risk remained doubled for those who slept more than 10 h daily with a HR of 2.14 [1.89, 2.42] which emerged as statistically significant (p-value < 0.05). Similarly, for individuals with cancer in this model, those who slept for 8 h/day had a HR of 1.15 [1.03,1.40] with a significant p-value < 0.05. There was a 25% (HR 1.25 [0.98, 1.59]), 36% (HR 1.36 [1.04, 1.64]), and 66% (HR 1.66 [1.28, 2.15]) heightened risk of mortality for those who slept ≤ 5 h/day, 9 h/day, and ≥ 10 h/day, with a p-value of 0.06, 0.08 and 0.06 respectively (Table 2, Adjusted Model 3).

A dose–response relation between SD and all-cause and cancer-specific mortality appeared to be J-shaped for the participants in the fully adjusted model (Fig. 2- Fig. A and Fig. B). The risk is lowest at around 6 to 8 h in the middle range of the curve and increases as it moves towards either end of extreme sleeping hours.

The findings from subgroup analyses by sex and age are summarized in Tables3 and 4. In Table 3, HR for mortality was found to significantly increase for both males and females, especially for long and short sleep duration. As adjustments were made to the models, the association between longer sleep durations and higher mortality became more pronounced. For males sleeping 9 h and ≥ 10 h, the

Table 3 Sleep duration and the risk of mortality stratified by sex

SD (h/day)	Participants, n	Deaths, n	Unadjusted model[a]		Adjusted model 1[b]		Adjusted model 2[c]		Adjusted model 3[d]	
			HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value
Male										
≤ 5 h	969	233	1.78 (1.53, 2.07)	< .0001	1.67 (1.42, 1.94)	< .0001	1.34 (1.14, 1.57)	0.0003	1.38 (1.14,1.57)	0.0003
6 h	2627	445	1.19 (1.05, 1.36)	0.005	1.23 (1.11, 1.42)	0.0005	1.13 (0.99, 1.28)	0.06	1.13 (1.00, 1.28)	0.06
7 h	3766	543	1 (reference)	–	1 (reference)	–	1 (reference)	–	1 (reference)	–
8 h	3822	861	1.64 (1.47, 1.83)	< 0.0001	1.50 (1.35, 1.68)	< .0001	1.38 (1.23, 1.53)	< .0001	1.38 (1.24, 1.53)	< .0001
9 h	482	171	2.84 (2.39, 3.37)	< 0.0001	2.38 (1.20, 2.82)	< .0001	1.95 (1.64, 2.32)	< .0001	1.95 (1.64, 2.32)	< .0001
≥ 10 h	467	214	4.20 (3.58, 4.91)	< 0.0001	3.30 (2.81, 3.87)	< .0001	2.37 (1.97, 2.74)	< .0001	2.32 (1.97, 2.74)	< .0001
Female										
≤ 5 h	1312	310	1.6 (1.62, 2.13)	< 0.001	1.68 (1.47, 1.93)	< 0.001	1.24 (1.08, 1.43)	0.002	1.24 (1.08, 1.43)	0.002
6 h	3071	490	1.19 (1.05, 1.37)	0.005	1.10 (0.96, 1.24)	0.13	1.02 (0.91, 1.16)	0.68	1.03 (0.91, 1.16)	0.68
7 h	4253	582	1 (reference)	–	1 (reference)	–	1 (reference)	–	1 (reference)	–
8 h	4784	902	1.43 (1.29, 1.52)	< 0.0001	1.33 (1.20, 1.48)	< .0001	1.23 (1.11, 1.36)	0.0001	1.23 (1.11, 1.36)	0.0001
9 h	784	208	2.14 (1.82, 2.13)	< 0.0001	2.00 (1.70, 2.34)	< 0.001	1.62 (1.38, 1.90)	< 0.0001	1.62 (1.38, 1.90)	< .0001
≥ 10 h	639	247	3.42 (2.95, 3.97)	< 0.0001	3.22 (2.78, 3.74)	< .0001	2.18 (1.87, 2.54)	< 0.0001	2.18 (1.87, 2.54)	< .0001

[a] Unadjusted Model: not adjusted for any covariate

[b] Adjusted Model 1: Adjusted for BMI, age

[c] Adjusted Model 2: Adjusted for age, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status

[d] Adjusted Model 3: Adjusted for age, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status, history of disease status, insurance type

SD Sleep duration *HR* Hazard ratio, *CI* Confidence interval, *BMI* Body mass index, *CHD* Coronary heart disease

Table 4 Sleep duration and the risk of mortality stratified by age

SD (h/day)	Participants, n	Deaths, n	Unadjusted model[a]		Adjusted model 1[b]		Adjusted model 2[c]		Adjusted model 3[d]	
			HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value
< 50 years										
≤ 5 h	1268	101	2.34 (1.83, 2.99)	< .0001	2.38 (1.86, 3.04)	< .0001	1.52 (1.19, 1.99)	0.001	1.52 (1.19,1.98)	0.001
6 h	3442	157	1.31 (1.06, 1.63)	0.01	1.31 (1.05, 1.62)	0.02	1.10 (0.88, 1.36)	0.38	1.10 (0.88, 1.36)	0.38
7 h	4985	174	1 (reference)	–	1 (reference)	–	1 (reference)	–	1 (reference)	–
8 h	4896	189	1.11 (0.90, 1.36)	0.33	1.13 (0.92, 1.38)	0.24	1.04 (0.84, 1.28)	0.69	1.04 (0.84, 1.28)	0.69
9 h	652	33	1.46 (1.00, 2.11)	0.05	1.56 (1.17, 2.27)	0.01	1.28 (0.88, 1.86)	0.19	1.28 (0.88, 1.89)	0.19
≥ 10 h	508	45	2.61 (1.88, 3.62)	< 0.0001	2.78 (1.99, 3.83)	< .0001	1.74 (1.23, 2.44)	0.001	1.75 (1.24, 2.44)	0.001
> 50 years										
≤ 5 h	973	239	1.56 (1.40, 1.77)	< 0.001	1.57 (1.40, 1.76)	< 0.001	1.23 (1.09, 1.38)	0.0004	1.23 (1.09, 1.38)	0.0004
6 h	2119	561	1.13 (1.03, 1.25)	0.008	1.15 (1.04, 1.26)	0.005	1.06 (0.96, 1.16)	0.24	1.06 (0.97, 1.16)	0.24
7 h	2881	441	1 (reference)	–	1 (reference)	–	1 (reference)	–	1 (reference)	–
8 h	3580	555	1.45 (1.39, 1.57)	< 0.0001	1.45 (1.34, 1.58)	< .0001	1.33 (1.23, 1.48)	< 0.0001	1.33 (1.23, 1.48)	0.0001
9 h	784	146	2.22 (1.96, 2.51)	< 0.0001	2.00 (1.70, 2.34)	< 0.001	1.81 (1.60, 2.05)	< 0.0001	1.82 (1.60, 2.07)	< .0001
≥ 10 h	639	172	3.31 (2.95, 3.72)	< 0.0001	3.32 (2.97, 3.79)	< .0001	2.31 (2.05, 2.60)	< 0.0001	2.31 (2.05, 2.60)	< .0001

[a] Unadjusted Model: not adjusted for any covariate

[b] Adjusted Model 1: Adjusted for BMI, sex

[c] Adjusted Model 2: Adjusted for sex, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status

[d] Adjusted Model 3: Adjusted for sex, BMI, race, smoking status, alcohol consumption status, physical activity, education status, hypertension status, stroke status, CHD status, history of disease status, insurance type

SD Sleep duration *HR* Hazard ratio, *CI* Confidence interval, *BMI* Body mass index, *CHD* Coronary heart disease

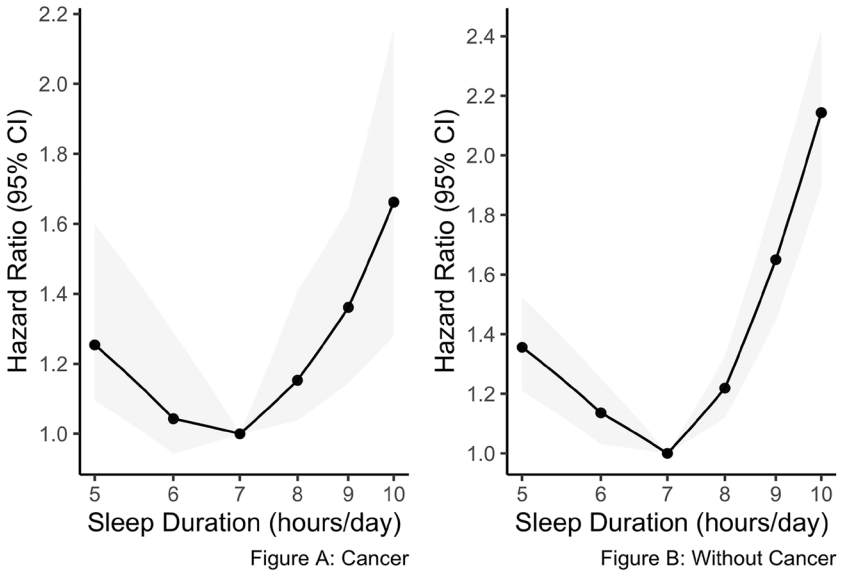

Fig. 2 Dose–response association between SD and all-cause and cancer-specific mortality

HR was significantly elevated at 1.95 (95% CI [1.64, 2.32]) and 2.32 (95% CI [1.97, 2.74]), respectively. Similarly for female participants sleeping 9 h and ≥ 10 h, the HR was significantly high at 1.62 [95% CI (1.38, 1.90)] and 2.18 (95% CI [1.87, 2.54]), respectively. In Table 4a similar trend was observed when stratified by age categories. Among participants aged < 50 years, significant increases in HR were found for those sleeping 9 h or more. Notably, for those aged > 50 years who slept 9 h and ≥ 10 h, the HR was substantially higher at 1.82 (95% CI [1.60, 2.07]) and 2.31 (95% CI [2.05, 2.60]), respectively. For those aged < 50 years who slept inadequately, the HR was found to be 1.52 (95% CI [1.19, 1.98]).

Discussion

Our findings suggest that excessive or insufficient sleep may be a risk factor for all-cause and cancer-specific mortality in participants with and without cancer. Wilun da and his colleagues also observed an increased risk of mortality associated with extremes (too little or too much) of SDs [19]. For individuals sleeping 10 h, the HR increases to 1.66 (95% CI [1.28, 2.15]) for cancer patients and 2.14 (95% CI [1.89, 2.42]) for non-cancer participants (Table 2-Adjusted Model 3). This aligns with the observations made by Wong and his colleagues, who found that both men and women who slept for over 10 h faced a higher risk of experiencing elevated mortality rates, as indicated by a significant increase in HR [13]. We also observed individuals sleeping ≤ 5 h have an increased mortality rate. HR increases to 1.25 (95% CI [0.98, 1.59]), with a p-value of 0.06 for cancer patients and 1.356 (95% CI [1.20, 1.52] with p-value < 0.05) for non-cancer participants (Table 2-Adjusted Model 3), also indicated by Lehrer, who claimed a significant correlation between insufficient sleep and all-cancer mortality [11]. According to NIH guidelines, healthy adults should aim for 7–9 h of sleep per day, as outlined on their website (https://www.nhlbi. nih. gov/health/sleep/how-much-sleep). The study conducted by Qiman also supports the idea that a 7-h SD is associated with the lowest risk for all-cause mortality [20]. Specifically, our study indicates that SD of 6–8 h is linked to the lowest risk among cancer patients and for non-cancer participants. We believe that 6 h of sleep is very close to 7 h and this study was based on self-reported data, which might have resulted in low mortality rates for participants sleeping for 6 h.

The dose–response associations between SD and mortality from all-cause and cancer-specific reasons appeared to be J-shaped in our study (Fig. 2) after adjusting for sex, age, race, BMI, and other significant variables, as also described by Wong [9]. However, Qiman described it as U-shaped [20]. The differences in findings can likely be attributed to variations in population characteristics, as well as methodological distinctions. For instance, this study specifically examines a sample of U.S. U.S.-based population focusing on mortality linked to SD with six categories of ≤ 5, 6, 7, 8, 9 and ≥ 10 h. Qiman investigated the association of mortality with SD categorized into five groups, precisely ≤ 5, 6, 7, 8, and ≥ 9 h [20]. Further research is needed to thoroughly investigate the variations in the dose–response relationship within the study population compared to other studies with similar variables. The subgroup analyses stratified by sex and age, summarized in Tables 3 and 4, further reveal a significant increase in hazard ratios (HR) for mortality associated with long sleep durations (9 h and ≥ 10 h) also mentioned by Yeo et al. and Wang et al. [16, 18].

Cancer patients frequently mention many symptoms adversely affecting the quality of their life, and most of them

mention sleep issues addressing fatigability [21]. To find out the rationale, Mercadante and his colleagues addressed probable associating factors affecting sleep and analyzed the prevalence of sleep disturbances among cancer patients concerning quality and quantity [2]. Furthermore, alterations in the endocrine functions, especially abnormal cortisol metabolism resulting from deranged and insufficient sleep, are plausibly responsible for the increased all-cancer mortality [7, 22–24]. Indeed, IL-6 and C-reactive protein, indicators of infection, are elevated in individuals who report long SD [23–25]. It is acknowledged, however, that sleep is a complex phenomenon, and extreme SD may reflect poorer health status and reduced functioning (e.g., our finding that people with cancer who sleep longer have greater mortality risk; such people may experience more severe cancer-related complications or adverse outcomes that require more rest or long-term bed rest). Another possible explanation of these findings is that longer SD has been associated with chronic inflammatory responses, which increase mortality risk [23, 26–29].

Our study has several strengths, including the relatively large sample size. Furthermore, the data includes individuals from different backgrounds and locations, and thus, the study's results can be generalized for the whole US population. The study considered data from individuals who had been diagnosed with different types of cancer. By including data from multiple types of cancer, this study can provide insights that apply across different cancer diagnoses, which can be particularly valuable for drawing more generalizable conclusions and making recommendations that have a broader reach in the medical and scientific community. The study also conducted stratified analysis by age and sex, which supported our primary findings while adjusting for significant predictors and has improved this study's scope of research.

Several limitations should also be noted. Although our sample size was substantial, it is important to note that the distribution of variables across categories was not uniform. Some categories had a limited number of observations, while others had more. This uneven distribution may introduce potential biases. SD, cancer diagnosis, and history were determined from a self-reported questionnaire without objective measurements [30–32]. Any measurement errors in the assessment of SD would most likely be non-differential and lead to underestimation of the observed associations because of the study's prospective design [26, 33–35]. Thus, HR estimates may be overestimated due to estimation bias caused by ignoring competing risks. Additionally, the study includes a one-time measurement of sleep parameters, and we lacked information on other factors that may be responsible for the deterioration of sleep quality (e.g., medications, anxiety/depression). Finally, we cannot rule out the residual or unmeasured confounding factors such as location, marital status, sleep disorders such as insomnia and sleep apnea, other comorbidities such as diabetes, insulin or other medication use, etc. Further studies in this area may concentrate on addressing such issues.

Conclusion

This study provides evidence that sleeping for significantly shorter or longer than 7–8 h per day appears to raise the risk of all-cause and cancer-specific mortality among individuals who have been diagnosed with cancer, especially for those sleeping longer than the recommended sleep duration. When comparing, the links between SD and mortality are also similar for participants without cancer, consistently showing an elevated hazard ratio. These individuals might benefit from intensified medical focus aimed at addressing sleep patterns, optimum amount of sleep, and overall lifestyle to mitigate the potential risks associated with adverse health outcomes.

Author contributions Purbasha Biswas, Tolulope V. Adebile, Wei Tu, and Lili Yu contributed to the writing, reviewing, and editing of the manuscript. Purbasha Biswas, Tolulope V. Adebile, Sarah Sejoro, Manyun Liu, Lili Yu, and Xinyan Zhang were involved in data cleaning, methodology, and the utilization of software. Purbasha Biswas and Lili Yu played roles in conceptualization, project management, data validation, and resource allocation. Formal analysis was conducted by Purbasha Biswas under the supervision of Lili Yu. All authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors affirm that they have no associations or engagements with any organization or entity possessing financial interests in the subject matter or materials addressed in this manuscript.

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