**Journal of Pioneering Medical Sciences**
Received: January 09, 2026 | Accepted: May 22, 2026 | Published: July 05, 2026
Volume 15, Issue 06, Pages 06-14

*DOI https://doi.org/10.47310/jpms2026150602*


# Age-Dependent Patterns of Short Sleep Among U.S. Adults with Arthritis: A Nationally Representative Analysis

**Mousa A. Albalwi**[1*]
[1]Department of Internal Medicine, Faculty of Medicine, University of Tabuk, Tabuk, Saudi Arabia

Author Designation: [1]Assistant Professor

*Corresponding author: Mousa A. Albalwi (e-mail: Mousa.Albalwi@ut.edu.sa).



**Abstract** **Background:** Sleep duration is a critical determinant of metabolic, psychological and physical health. Arthritis is highly prevalent among adults and frequently coexists with sleep disturbances; however, evidence examining whether arthritis independently increases the risk of short sleep duration remains inconsistent. **Objective:** To evaluate whether adults with arthritis (including osteoarthritis [OA] and Rheumatoid Arthritis [RA]) have higher odds of short sleep (<7 hours/night) and whether age modifies this association. **Methods:** We analyzed 9,160 adults aged ≥20 years from NHANES 2015-2018, applying the complex survey design and 4-year MEC examination weights. Arthritis status (none, OA, RA) was self-reported. Sleep duration was categorized as short sleep (<7 hours). Survey-weighted descriptive statistics and logistic regression models were performed (unadjusted, demographic-adjusted and fully adjusted). Age was mean-centered at 50.22 years. Subtype-specific and sex-stratified analyses were conducted and interaction terms tested effect modification by age. **Results:** Adults with arthritis were older and had higher BMI and smoking prevalence than those without arthritis. Overall, 22.0% of adults reported short sleep (<7 hours/night), with comparable prevalence in those with (21.8%) and without (22.1%) arthritis. In fully adjusted models, arthritis did not independently predict short sleep (adjusted odds ratio [AOR] 1.14, 95% CI 0.98-1.32, p = 0.112). However, the arthritis×age interaction was significant (AOR 0.97, 95% CI 0.97-0.98, p<0.001), indicating age-dependent differences in predicted probability of short sleep. OA but not RA demonstrated a significant age interaction (OA×age AOR 0.97, p = 0.001; RA×age AOR 1.00, p = 0.897). Sex-stratified models showed similar patterns. **Conclusions:** Arthritis was not independently associated with short sleep after full adjustment but age meaningfully modified this relationship. Sleep health interventions may require age-specific strategies in adults with arthritis.

**Key Words** Arthritis, Short Sleep, Osteoarthritis, Rheumatoid Arthritis, NHANES, Age Interaction

## INTRODUCTION

Sleep duration is a fundamental biological necessity with broad implications for physical, metabolic and psychological health. A substantial body of evidence demonstrates that insufficient sleep contributes to cardiovascular disease, obesity, type 2 diabetes, impaired cognitive function and increased mortality [1-4]. Short sleep duration-defined as fewer than seven hours per night-is now recognized as a significant public health issue affecting nearly one-third of U.S. adults [5-7]. At the same time, arthritis remains one of the most prevalent chronic conditions in the United States, affecting more than 58 million adults and representing a major cause of pain, disability and reduced quality of life [8].

Osteoarthritis (OA) and Rheumatoid Arthritis (RA), the two most common arthritis subtypes, have distinct pathophysiologic mechanisms. OA is primarily characterized by mechanical degeneration and synovial inflammation, while RA is a systemic autoimmune disease driven by inflammatory cytokines such as TNF-α and IL-6. Both conditions are frequently accompanied by sleep disturbances. Prior clinical and cohort studies report that 50-70% of individuals with arthritis experience poor sleep quality, insomnia or non-restorative sleep [9-12]. Pain, joint stiffness, nocturnal discomfort, depressive symptoms and inflammatory cytokine activity are all believed to contribute to sleep difficulties in arthritis [13-16].

However, the relationship between arthritis and sleep duration-distinct from sleep quality-remains poorly understood and prior studies have reported inconsistent findings. Some evidence suggests that chronic pain conditions, including osteoarthritis and rheumatoid arthritis, may be associated with shorter sleep duration, particularly among younger individuals with more active disease [7]. Sleep architecture and the experience of pain-related sleep

disturbance also vary by sex, with women generally reporting greater sleep disturbance than men, including in arthritis populations [17]. In contrast, studies in older adults with arthritis often describe age-related changes in sleep patterns, daily routines and functional activity that may alter how sleep duration is reported or experienced, independent of disease status [18-20]. Collectively, these observations raise a critical question: does age modify the association between arthritis and short sleep duration?

The National Health and Nutrition Examination Survey (NHANES) offers an ideal platform to address this question. NHANES provides nationally representative data with standardized assessments of sleep duration, anthropometric measures, sociodemographic characteristics and chronic health conditions. Importantly, NHANES includes separate categorizations for OA and RA, enabling more nuanced evaluation of arthritis subtypes. Despite the availability of these data, a clear research gap persists: few studies have assessed arthritis subtypes separately, tested whether age modifies arthritis-sleep associations at a population level or evaluated whether these patterns differ by sex. Addressing this gap is essential because age-dependent and subtype-specific differences directly inform whether uniform or tailored sleep-management strategies are appropriate in clinical practice.

### Objectives

The present study addresses the above gap by pursuing three pre-specified objectives: (1) To estimate the association between self-reported arthritis (overall) and short sleep duration in a nationally representative sample of U.S. adults; (2) To compare osteoarthritis- and rheumatoid-arthritis-specific associations with short sleep and (3) To test whether age modifies these relationships, with sex-stratified analyses to identify gender-specific patterns. Clarifying whether arthritis independently predicts short sleep-and whether this relationship changes across age groups-is clinically relevant, as age- and subtype-tailored sleep interventions may be required for adults with arthritis.

## MATERIALS AND METHODS

### Study Design and Data Source

This cross-sectional study used data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative survey of the civilian, non-institutionalized U.S. population conducted using a complex, multistage probability sampling design. Data from the 2015-2016 and 2017-2018 cycles were combined according to NHANES analytic guidelines to create a 4-year dataset. All analyses incorporated Mobile Examination Center (MEC) sampling weights, strata and primary sampling units to account for the complex survey design.

### Study Population and Eligibility

Adults aged ≥20 years who completed the MEC examination were eligible. Inclusion required complete responses for the primary exposure (arthritis status) and outcome (sleep duration) and valid four-year MEC sampling weights. Specifically, participants were excluded if they (a) Were aged <20 years, (b) Self-reported pregnancy at the time of MEC examination, (c) Had missing values on the arthritis status item, (d) Had missing or implausible sleep-duration values or (e) Lacked a four-year MEC examination sampling weight (WTMEC4YR). Participants with missing data on any included covariate (age, sex, race/ethnicity, education, poverty-income ratio, body mass index, smoking status) were excluded from regression models to permit complete-case survey-weighted analyses; missingness was <5% for any single covariate and a sensitivity check confirmed that demographic distributions of excluded and retained participants were similar. The final analytic sample included 9,160 participants with complete data suitable for survey-weighted analyses. Participant flow is depicted in Figure 1 and the distribution of the final sample by arthritis subtype is provided in Supplementary Table S1.

### Exposure: Arthritis Status

Arthritis status was determined by self-reported physician diagnosis. The primary exposure compared participants with any arthritis to those without arthritis. In subtype analyses, arthritis was classified as osteoarthritis (OA) or Rheumatoid Arthritis (RA). Participants reporting psoriatic or other arthritis types were excluded from subtype models due to small sample sizes.

### Outcome: Self-Reported Sleep Duration

Sleep duration was assessed by self-report of usual weekday or workday sleep hours. Sleep was analyzed as a continuous variable and dichotomized as short sleep (<7 hours/night) versus normal sleep (≥7 hours/night).

### Covariates

Covariates were selected a priori based on established associations with arthritis and sleep. These included age (mean-centered at 50.22 years), sex, race/ethnicity, education level, Poverty-Income Ratio (PIR), Body Mass Index (BMI) and smoking status (never, former, current). All covariates were derived from NHANES interview or examination components. Rationale for inclusion: age and sex influence both arthritis prevalence and sleep architecture; race/ethnicity, education and PIR capture socioeconomic and environmental determinants of sleep opportunity and health-care access; BMI is a shared risk factor for arthritis progression, joint loading and sleep-disordered breathing; and smoking status influences systemic inflammation and sleep continuity. Age was mean-centered to improve interpretability of interaction terms and reduce multicollinearity between the main effect and the interaction product.

### Statistical Analysis

Descriptive statistics were summarized using survey-weighted means, standard deviations and proportions. Group differences were assessed using survey-weighted linear

regression or chi-square tests, as appropriate. Survey-weighted logistic regression models examined associations between arthritis status and short sleep. Three models were specified: unadjusted; demographic-adjusted (age, sex, race/ethnicity); and fully adjusted (demographic variables plus BMI, smoking status, education and PIR). Effect modification by age was assessed by including interaction terms between arthritis status and centered age. Subtype analyses compared OA and RA with no arthritis and additional models were restricted to participants with arthritis. Sex-stratified analyses were also conducted using fully adjusted models.

All analyses incorporated the NHANES complex survey design using strata (SDMVSTRA), primary sampling units (SDMVPSU) and four-year MEC examination weights (WTMEC4YR) via the R survey package (svydesign function), producing nationally representative estimates with appropriate Taylor-series linearization for variance estimation. Prior to fitting multivariable models, multicollinearity was assessed using variance inflation factors (VIFs); all covariates had VIFs <2, indicating no concerning collinearity. Predicted probabilities of short sleep across age were estimated from survey-weighted models and visualized graphically. All analyses were conducted using R version 4.5.2 with the survey package. Statistical significance was defined as a two-sided p-value <0.05.

### Data Security and Confidentiality

NHANES public-use datasets are fully de-identified at the source by the National Center for Health Statistics (NCHS); no directly identifiable information was accessed during this secondary analysis. All data were downloaded from the official NHANES portal and stored on a password-protected institutional workstation. Analyses were conducted in accordance with NCHS data-use guidance and standard research-data security practice.

## RESULTS

### Study Sample Characteristics

A total of 9,160 adults aged ≥20 years met inclusion criteria after combining NHANES 2015-2016 and 2017-2018 cycles, applying MEC examination weights and excluding participants with missing data or pregnancy. This weighted sample represented approximately 207.9 million U.S. adults. Participant selection is summarised in Figure 1 and the numeric distribution of the final sample by arthritis subtype is provided in Supplementary Table S1. Participants were categorized according to arthritis status and subtype.

Weighted descriptive characteristics are summarized in Table 1. The weighted sample included 151.2 million adults without arthritis and 56.7 million with arthritis; participants with arthritis were older and differed across multiple demographic and health factors.

### Association Between Arthritis and Short Sleep Duration

Survey-weighted logistic regression models examined whether arthritis status was associated with short sleep duration (<7 hours). Three models were estimated: unadjusted (Model 1), demographic-adjusted (Model 2) and fully adjusted (Model 3). Results are summarized in Table 2.

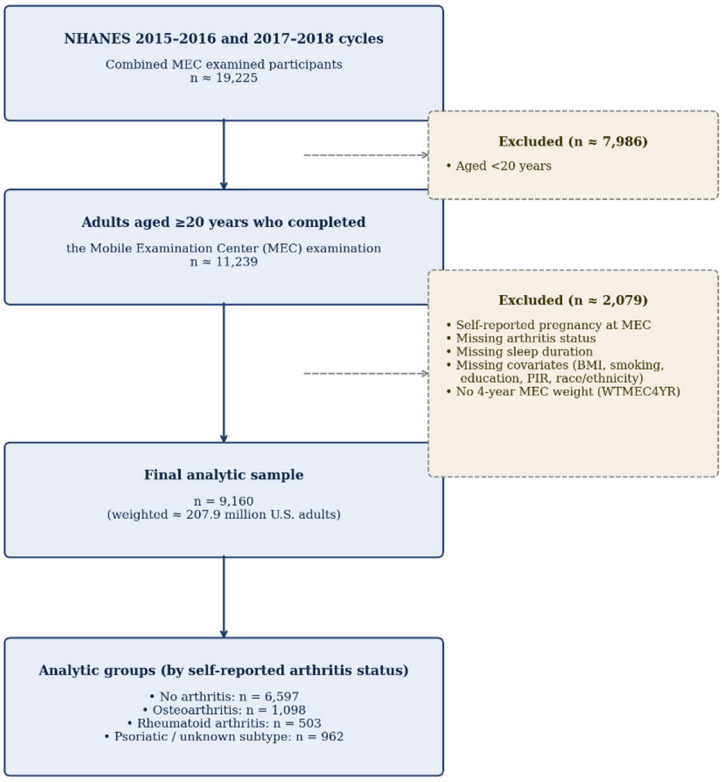


Figure 1: Flow Diagram of Participant Inclusion and Exclusion, NHANES 2015-2018

Table 1: Socio-Demographic and Health Characteristics of the Study Population by Arthritis Status, NHANES 2015-2018

| Characteristic | Overall (N = 9,160) | No arthritis (n = 6,597) | Arthritis (n = 2,563) | p-value |
|---|---|---|---|---|
| Age, mean (SD), years | 48.0 (17.02) | 43.4 (15.91) | 60.3 (13.46) | <0.001 |
| **Sex (n (%))** | | | | |
| Female | 106,804,876 (51.4%) | 73,101,634 (48.3%) | 33,703,241 (59.5%) | <0.001 |
| Male | 101,094,349 (48.6%) | 78,116,378 (51.7%) | 22,977,971 (40.5%) | |
| **Sleep status** | | | | |
| Sleep hours, mean (SD) | 7.6 (1.45) | 7.6 (1.40) | 7.7 (1.58) | 0.011 |
| Short sleep (<7 hours), n (%) | 45,744,952 (22.0%) | 33,378,571 (22.1%) | 12,366,381 (21.8%) | 0.800 |
| **Race/Ethnicity (n (%))** | | | | |
| Mexican American | 17,293,637 (8.3%) | 14,889,302 (9.8%) | 2,404,335 (4.2%) | <0.001 |
| Non-Hispanic Asian | 11,617,367 (5.6%) | 10,199,813 (6.7%) | 1,417,554 (2.5%) | |
| Non-Hispanic Black | 22,528,565 (10.8%) | 17,013,436 (11.3%) | 5,515,129 (9.7%) | |
| Non-Hispanic White | 134,900,304 (64.9%) | 92,982,804 (61.5%) | 41,917,500 (74.0%) | |
| Other Hispanic | 12,824,413 (6.2%) | 10,408,133 (6.9%) | 2,416,280 (4.3%) | |
| Other/Multiracial | 8,734,938 (4.2%) | 5,724,524 (3.8%) | 3,010,413 (5.3%) | |
| Body mass index, mean (SD) | 29.6 (7.15) | 28.9 (6.92) | 31.4 (7.42) | <0.001 |
| Poverty-income ratio, mean (SD) | 3.0 (1.64) | 3.0 (1.64) | 3.1 (1.64) | 0.900 |
| **Education level (n (%))** | | | | |
| College graduate | 66,744,255 (32.1%) | 51,364,100 (34.0%) | 15,380,155 (27.1%) | 0.002 |
| High school graduate (HS) | 49,961,578 (24.0%) | 35,496,923 (23.5%) | 14,464,655 (25.5%) | |
| Less than HS | 24,858,129 (12.0%) | 17,549,064 (11.6%) | 7,309,065 (12.9%) | |
| Some college/Associate of Arts (AA) | 66,335,263 (31.9%) | 46,807,925 (31.0%) | 19,527,338 (34.5%) | |
| **Smoking status (n (%))** | | | | |
| Current | 36,485,886 (17.5%) | 25,946,377 (17.2%) | 10,539,509 (18.6%) | <0.001 |
| Former | 53,018,509 (25.5%) | 33,647,035 (22.3%) | 19,371,473 (34.2%) | |
| Never | 118,394,830 (56.9%) | 91,624,600 (60.6%) | 26,770,230 (47.2%) | |

n (%): Weighted frequency (column percentage), SD: Standard deviation, p-value from survey-weighted t-test for continuous and chi-square ($\chi^2$) test for categorical variables, Analysis uses survey-weighted descriptive statistics with NHANES complex survey design (strata, PSUs and 4-year examination weight [wtmec4yr])

Table 2: Survey-Weighted Logistic Regression for Association Between Self-Reported Arthritis and Short Sleep Duration, NHANES 2015-2018

| Predictor | Model 1 OR (95% CI) | p | Model 2 aOR (95% CI) | p | Model 3 aOR (95% CI) | p |
|---|---|---|---|---|---|---|
| Arthritis (yes vs. no) | 0.99 (0.86-1.13) | 0.830 | 1.26 (1.10-1.45) | 0.004 | 1.14 (0.98-1.32) | 0.112 |
| Age (centered, per year) | - | - | 1.00 (1.00-1.01) | 0.055 | 1.01 (1.00-1.01) | 0.040 |
| Interaction: Arthritis×age (centered) | - | - | 0.97 (0.96-0.98) | <0.001 | 0.97 (0.97-0.98) | <0.001 |

Model 1: Unadjusted, Model 2: Adjusted for age, sex, race/ethnicity, Model 3: Fully adjusted for all listed covariates, cells with "-" indicate the variable is not applicable to that model, age centered at the mean of 50.22 years, OR: Crude odds ratio, aOR: Adjusted odds ratio, CI: Confidence interval, HS: High school, Ref: Reference, Analysis uses survey-weighted logistic regression accounting for NHANES complex survey design (strata, PSUs and 4-year examination weight [wtmec4yr])

Table 2 summarises the survey-weighted logistic regression models. Arthritis was not associated with short sleep in the unadjusted model (OR = 0.99, 95% CI: 0.86-1.13, p = 0.830). After adjustment for age, sex and race/ethnicity (Model 2), arthritis was associated with higher odds of short sleep (aOR = 1.26, 95% CI: 1.10-1.45, p = 0.004) but the association was attenuated and not statistically significant in the fully adjusted model (aOR = 1.14, 95% CI: 0.98-1.32, p = 0.112). The arthritis × age interaction remained highly significant across adjusted models (p<0.001), indicating meaningful age-dependent differences. The fully adjusted odds-ratio estimates for all covariates are shown in Figure 2.

### Arthritis Subtype Analyses: Osteoarthritis and Rheumatoid Arthritis

Subtype analyses compared adults with OA and RA to those without arthritis using fully adjusted survey-weighted logistic regression; key estimates are summarized in Table 3.

Neither OA nor RA showed a statistically significant independent association with short sleep duration after full adjustment (OA, aOR = 1.09, 95% CI: 0.87-1.38, p = 0.464; RA, aOR = 1.15, 95% CI: 0.81-1.63, p = 0.440). However, the OA×age interaction was statistically significant, indicating a decreasing probability of short sleep with increasing age among adults with OA (aOR = 0.97, 95% CI: 0.95-0.98, p = 0.001). The RA×age interaction was not statistically significant (aOR = 1.00, 95% CI: 0.98-1.02, p = 0.897).

### Comparing RA vs. OA Among Arthritis Patients Only

A separate model restricted to participants with OA or RA compared short sleep between subtypes; full estimates are provided in Supplementary Table S2. RA did not differ significantly from OA with respect to odds of short sleep after full adjustment (aOR = 1.04, 95% CI: 0.65-1.64, p = 0.879). The interaction term (RA × age) was statistically significant, indicating that the age-related pattern of short sleep differed between RA and OA. For RA, the odds of short sleep increased modestly with age relative to OA (aOR = 1.03, 95% CI: 1.01-1.06), whereas OA showed decreasing probability of short sleep with age in prior models.

### Sex-Stratified Analyses

Sex-specific fully adjusted models were estimated to examine whether associations differed between men and women; results are provided in Supplementary Table S3. Among men, arthritis was not significantly associated with short sleep (aOR = 1.21, 95% CI: 0.92-1.59, p = 0.188) and

Table 3: Survey-Weighted Logistic Regression for Association Between Arthritis Subtypes (OA and RA vs. No Arthritis) and Short Sleep Duration, NHANES 2015-2018

| Predictor | aOR (95% CI) | p-value |
|---|---|---|
| **Arthritis Type (ref: No Arthritis)** | | |
| Osteoarthritis | 1.09 (0.87-1.38) | 0.464 |
| Rheumatoid arthritis | 1.15 (0.81-1.63) | 0.440 |
| **Age Terms** | | |
| Age (centered, per year) | 1.01 (1.00-1.01) | 0.032 |
| Osteoarthritis×age | 0.97 (0.95-0.98) | 0.001 |
| Rheumatoid arthritis×age | 1.00 (0.98-1.02) | 0.897 |
| **Sex (ref: Female)** | | |
| Male | 1.53 (1.32-1.76) | <0.001 |
| **Race/Ethnicity (ref: Non-Hispanic White)** | | |
| Non-Hispanic Black | 2.13 (1.70-2.66) | <0.001 |
| Non-Hispanic Asian | 1.26 (1.04-1.54) | 0.038 |
| Other Hispanic | 1.77 (1.29-2.42) | 0.004 |
| Mexican American | 1.21 (1.03-1.42) | 0.036 |
| Other/Multiracial | 1.07 (0.80-1.44) | 0.667 |
| **Anthropometrics** | | |
| BMI (per 1 kg/m²) | 1.02 (1.01-1.03) | <0.001 |
| **Smoking Status (ref: Never)** | | |
| Former | 1.08 (0.89-1.31) | 0.438 |
| Current | 1.58 (1.33-1.88) | <0.001 |
| **Education (ref: College Graduate/above)** | | |
| Some college/AA | 1.51 (1.23-1.86) | 0.002 |
| HS graduate/GED | 1.58 (1.23-2.03) | 0.004 |
| Less than HS | 1.33 (0.98-1.81) | 0.095 |
| **Socioeconomic Status** | | |
| Poverty-income ratio (PIR) | 1.07 (1.01-1.13) | 0.040 |

aOR: Adjusted odds ratio, CI: Confidence interval, Age centered at the mean of 50.22 years, HS: High school, Ref: Reference. Analysis uses survey-weighted logistic regression accounting for NHANES complex survey design (strata, PSUs and 4-year examination weight [wtmec4yr])

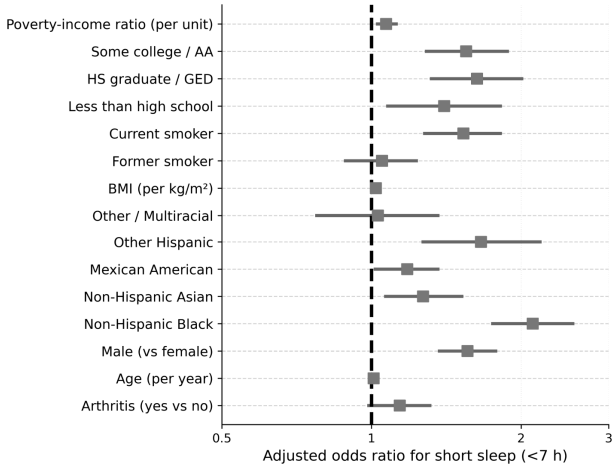


Figure 2: Adjusted Odds Ratios for Short Sleep (<7 Hours) from the Fully Adjusted Survey-Weighted Logistic Regression Model (Table 2)

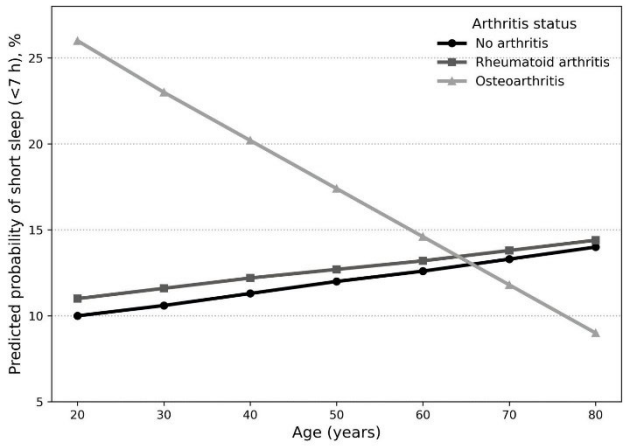


Figure 3: Predicted Probability (Percentage) of Short Sleep (<7 hours) by Age and Arthritis Type Based on Survey-Weighted Logistic Regression with Age×Arthritis Interaction (Table 3)

the arthritis×age interaction remained significant. Among women, arthritis was also not associated with short sleep (aOR = 1.04, 95% CI: 0.87-1.25, p = 0.686) and the interaction term showed a similar significant pattern. Additional covariate associations-such as racial/ethnic differences and effects of BMI, smoking and education-were observed across both sexes but were not central to the study's primary exposure-outcome relationship.

## Interaction Plot

To illustrate how the association between arthritis subtype and short sleep probability changes across the adult age range, predicted probabilities were derived from survey-weighted logistic models with centered age and are presented in Figure 3.

As shown in Figure 3, the predicted probability of short sleep varied by arthritis status across age. Among adults with osteoarthritis, short sleep probability was highest at younger ages and declined progressively with increasing age. In contrast, adults with rheumatoid arthritis exhibited a modest age-related increase in the predicted probability of short sleep, similar in direction but slightly higher in magnitude than the no-arthritis reference group. These divergent age-related trajectories highlight a significant arthritis-by-age

interaction, indicating that the relationship between arthritis and short sleep differs across the adult age spectrum.

## DISCUSSION

This nationally representative analysis of U.S. adults provides an important and nuanced assessment of the relationship between arthritis and short sleep duration, taking into account arthritis subtypes, a comprehensive set of covariates and the modifying effect of age. Although sleep disturbances are widely recognized as common in arthritis populations, the present study demonstrates that arthritis itself is not independently associated with short sleep after full adjustment, despite substantial differences in demographic and behavioral risk factors. Instead, a more meaningful finding emerged: age significantly modifies the association between arthritis and short sleep, revealing distinct patterns across the lifespan that conventional models without interaction terms fail to capture.

The observation that arthritis was not associated with short sleep in fully adjusted models contrasts with smaller clinical studies reporting that individuals with arthritis-particularly those with OA or RA-have shorter sleep duration or greater difficulty maintaining sleep [1-4]. Much of the earlier literature focuses on sleep quality, insomnia symptoms or objective sleep impairments rather than sleep duration per se. Pain severity, nocturnal pain, functional limitations and systemic inflammation have all been implicated as contributors to disturbed sleep in arthritis populations [5-7]. However, sleep duration alone may follow different patterns from sleep quality and this distinction likely explains some discrepancies with prior studies. In many rheumatic conditions, patients may sleep sufficiently long hours but experience fragmented, non-restorative sleep; thus, short sleep duration does not necessarily capture the breadth of sleep dysfunction in these populations [10].

The age interaction findings offer important insight into this complexity. Younger adults with arthritis-particularly those with osteoarthritis-demonstrated a higher probability of short sleep, with this probability declining progressively with increasing age. In contrast, rheumatoid arthritis was characterized by a more modest, age-related increase in short sleep probability, resembling the pattern observed among adults without arthritis.

Several mechanisms may explain these differential patterns. Younger and middle-aged adults with arthritis often experience high levels of mechanical joint stress, work-related limitations, caregiving burdens or early-onset functional impairment, all of which may contribute to poorer sleep hygiene or reduced sleep opportunity [9]. Chronic pain conditions in younger adults have also been associated with higher sympathetic activation, delayed sleep timing and increased sleep fragmentation [10]. Additionally, younger OA patients, though less common in the general population, may have post-traumatic or occupationally acquired OA phenotypes that present with more severe or activity-related symptoms.

The declining probability of short sleep with increasing age among adults with OA may reflect behavioural and structural lifestyle changes. Older adults frequently have fewer occupational constraints, more flexible schedules and more time available for rest. Retirement also reduces sleep curtailment imposed by early work hours. Moreover, older adults with OA often adopt pacing strategies, regular analgesic regimens or daytime rest periods that may indirectly support longer nocturnal sleep duration [11]. Some studies suggest that aging is accompanied by substantial changes in sleep patterns and sleep perception, including increased sleep fragmentation, reduced sleep efficiency and less reliable self-reporting of sleep duration, particularly among individuals with chronic pain conditions [12,13]. As a result, the relationship between osteoarthritis and short sleep duration may appear attenuated at older ages, even in the presence of ongoing sleep disturbance. This dissociation highlights the importance of evaluating sleep quality, rather than sleep duration alone, when assessing sleep-related burden in adults with arthritis.

The absence of a significant age interaction in RA when compared to no arthritis but its presence in the RA vs. OA comparison, is notable. RA is characterized by systemic inflammation, often accompanied by fatigue, cytokine fluctuations and comorbidity profiles that differ substantially from OA. While OA is predominantly a degenerative joint disease with pain exacerbations influenced by activity, RA involves chronic immune dysregulation with episodic flares. Cytokines such as TNF-α, IL-1β and IL-6-which are elevated in RA-directly influence sleep regulation and circadian pathways [14-16]. These mechanisms may help stabilize sleep duration across age in RA patients, even while they continue to experience qualitative sleep impairment or fatigue. The slight increase in short-sleep probability with age among RA patients in subtype analyses may reflect age-related comorbidity accumulation, polypharmacy or changes in inflammatory burden.

Sex-stratified analyses revealed similar arthritis × age interaction patterns in both men and women, suggesting that the modifying effect of age is robust across genders. Nevertheless, sex-specific differences emerged in covariate associations. Women, for example, showed a modest positive association between age and short sleep independent of arthritis, consistent with established literature showing increased insomnia complaints and sleep maintenance difficulties in older women [17,18]. Men, on the other hand, demonstrated stronger associations between smoking, educational attainment and short sleep-patterns consistent with prior U.S. population studies. These findings reinforce the importance of sex as a contextual factor in epidemiologic sleep research, even when it does not directly modify the primary exposure-outcome relationship.

## CONCLUSIONS

In this nationally representative analysis, arthritis was not independently associated with short sleep duration after full adjustment; instead, age modified the relationship between arthritis and sleep. Younger adults with arthritis, particularly those with osteoarthritis, had a higher probability of short sleep, with attenuation at older ages, whereas rheumatoid arthritis followed a distinct age-related pattern. These findings emphasize the need for age- and subtype-specific approaches to sleep assessment in arthritis populations and

suggest that sleep duration alone is insufficient to characterize sleep-related burden. Practically, clinicians caring for younger adults with osteoarthritis should incorporate routine short-sleep screening and pain-sleep co-management, while older adults with arthritis warrant assessment of sleep quality alongside duration. At the public-health level, age- and subtype-tailored sleep guidance-rather than uniform duration-based targets-should inform arthritis care pathways. Longitudinal studies incorporating objective sleep measures are needed to clarify mechanisms and inform targeted interventions.

### Strengths

Several strengths of this study deserve emphasis. First, the use of nationally representative NHANES data with appropriate complex-survey weighting enhances generalisability across diverse U.S. adult populations. Second, the comprehensive adjustment for socio-demographic and behavioural confounders-including socioeconomic status, BMI, smoking and education-addresses important shared pathways that have inflated arthritis-sleep associations in earlier work. Third, the separate analysis of OA and RA, rather than treating arthritis as a single homogeneous category, yields clinically meaningful granularity rarely addressed in population-level studies. Fourth, the explicit testing of age×arthritis interaction terms reveals lifespan-dependent patterns that conventional main-effects models would obscure.

### Clinical and Public Health Implications

Clinically, the age-dependent and subtype-specific patterns observed here suggest that sleep assessment in adults with arthritis should be tailored to age rather than treated uniformly. Younger adults with arthritis-particularly those with osteoarthritis-may benefit from earlier and more proactive screening for short sleep, combined with behavioural interventions targeting sleep hygiene, pain-sleep co-management and work-related stressors. Older adults with arthritis, in contrast, may continue to experience fragmented or non-restorative sleep despite apparent adequacy of sleep duration; in this group, clinical attention should extend beyond sleep duration to incorporate sleep-quality assessment, screening for sleep-disordered breathing and medication review for sleep-disrupting agents. From a public-health perspective, these findings argue against uniform duration-based sleep targets in arthritis populations and support the integration of age- and subtype-stratified sleep screening into primary-care and rheumatology workflows.

### Future Research Directions

Building on these observations, future research should:

- Conduct longitudinal studies to clarify the temporal direction of the arthritis-sleep relationship and identify age-specific causal pathways
- Incorporate objective sleep measures (actigraphy, polysomnography) and validated sleep-quality instruments (e.g., PSQI, ISI) alongside duration metrics
- Integrate inflammatory biomarkers (CRP, IL-6, TNF-α) and clinically measured pain severity to dissect biological mechanisms underlying age-dependent patterns
- Stratify subsequent analyses by functional status, disease activity and medication use, including disease-modifying anti-rheumatic drugs and analgesics
- Test age- and subtype-tailored sleep interventions in pragmatic trials embedded in rheumatology and primary-care settings
- Replicate findings in non-U.S. cohorts to assess cross-cultural generalisability of age×arthritis×sleep relationships

## Limitations

However, several limitations should be considered. First, arthritis status was self-reported, which may introduce misclassification bias, particularly for OA and RA, which ideally require clinical and radiographic confirmation. Second, sleep duration was self-reported and measured in whole hours, limiting precision and failing to capture sleep quality, circadian patterns or nocturnal pain disruptions; actigraphy or polysomnography would provide more accurate sleep metrics but are not available in NHANES. Third, the cross-sectional design precludes causal inference. Fourth, certain arthritis subtypes (e.g., psoriatic arthritis) had small sample sizes and thus could not be meaningfully included in subtype analyses. Fifth, residual confounding from unmeasured variables-including depression, anxiety, pain severity, sleep apnea and use of sleep medications-may persist. Finally, although NHANES is nationally representative of the non-institutionalised U.S. adult population, the findings may not generalize directly to institutionalised older adults or to populations outside the United States, where socio-environmental determinants of sleep differ.

## Acknowledgement

The author thanks the National Center for Health Statistics (NCHS) and the Centers for Disease Control and Prevention (CDC) for conducting the National Health and Nutrition Examination Survey (NHANES) and for providing access to publicly available data.

## REFERENCES

[1] Itani, O. *et al.* "Short Sleep Duration and Health Outcomes: A Systematic Review, Meta-Analysis and Meta-Regression." *Sleep Medicine*, vol. 32, 2017, pp. 246-256. https://doi.org/10.1016/j.sleep.2016.08.006.

[2] Grandner, M.A. "Sleep, Health and Society." *Sleep Medicine Clinics*, vol. 12, 2017, pp. 1-22. https://doi.org/10.1016/j.jsmc.2016.10.012.

[3] Consensus Conference Panel *et al.* "Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society on the Recommended Amount of Sleep for a Healthy Adult: Methodology and Discussion." *Sleep*, vol. 38, 2015, pp. 1161-1183. https://doi.org/10.5665/sleep.4886.

[4] Medic, G. *et al.* "Short- and Long-Term Health Consequences of Sleep Disruption." *Nature and Science of Sleep*, vol. 9, 2017, pp. 151-161. https://doi.org/10.2147/NSS.S134864.

[5] Finan, P.H. *et al.* "The Association of Sleep and Pain: An Update and a Path Forward." *The Journal of Pain*, vol. 14, 2013, pp. 1539-1552. https://doi.org/10.1016/j.jpain.2013. 08.007.

[6] Haack, M. *et al.* "Pain Sensitivity and Modulation in Primary Insomnia." *European Journal of Pain*, vol. 16, 2012, pp. 522-533. https://doi.org/10.1016/j.ejpain.2011.07.007.

[7] Irwin, M.R. "Sleep and Inflammation: Partners in Sickness and in Health." *Nature Reviews Immunology*, vol. 19, 2019, pp. 702-715. https://doi.org/10.1038/s41577-019-0190-z.

[8] Zhang, Y. and J.M. Jordan. "Epidemiology of Osteoarthritis." *Clinics in Geriatric Medicine*, vol. 26, 2010, pp. 355-369. https://doi.org/10.1016/j.cger.2010.03.001.

[9] Irwin, M.R. *et al.* "Heat of the Night: Sleep Disturbance Activates Inflammatory Mechanisms and Induces Pain in Rheumatoid Arthritis." *Nature Reviews Rheumatology*, vol. 19, 2023, pp. 545-559. https://doi.org/10.1038/s41584-023-00997-3.

[10] Tang, N.K.Y. *et al.* "Deciphering the Temporal Link between Pain and Sleep in a Heterogeneous Chronic Pain Patient Sample: A Multilevel Daily Process Study." *Sleep*, vol. 35, 2012, pp. 675-687A. https://doi.org/10.5665/sleep.1830.

[11] Parmelee, P.A. *et al.* "Sleep Disturbance in Osteoarthritis: Linkages with Pain, Disability and Depressive Symptoms." *Arthritis Care & Research*, vol. 67, 2015, pp. 358-365. https://doi.org/10.1002/acr.22459.

[12] Miner, B. and M.H. Kryger. "Sleep in the Aging Population." *Sleep Medicine Clinics*, vol. 12, 2017, pp. 31-38. https://doi.org/10.1016/j.jsmc.2016.10.008.

[13] Crowley, K. "Sleep and Sleep Disorders in Older Adults." *Neuropsychology Review*, vol. 21, 2011, pp. 41-53. https://doi.org/10.1007/s11065-010-9154-6.

[14] James M. Krueger *et al.* "Cytokines in immune function and sleep regulation." *Handbook of Clinical Neurology*, vol. 98, 2011, pp. 229-240. https://pmc.ncbi.nlm.nih.gov/articles/PMC5440845/.

[15] Austad, C. *et al.* "Sleep Disturbance in Patients with Rheumatoid Arthritis Is Related to Fatigue, Disease Activity and Other Patient-Reported Outcomes." *Scandinavian Journal of Rheumatology*, vol. 46, 2017, pp. 95-103. https://doi.org/10.3109/03009742.2016.1168482.

[16] Wang, D. *et al.* "Pain Mechanism and Management Strategy of Rheumatoid Arthritis." *Frontiers in Pain Research*, vol. 6, 2025. https://doi.org/10.3389/fpain.2025.1693399.

[17] Mallampalli, M.P. and C.L. Carter. "Exploring Sex and Gender Differences in Sleep Health: A Society for Women's Health Research Report." *Journal of Women's Health*, vol. 23, 2014, pp. 553-562. https://doi.org/10.1089/jwh.2014.4816.

[18] Zeng, L.N. *et al.* "Gender Difference in the Prevalence of Insomnia: A Meta-Analysis of Observational Studies." *Frontiers in Psychiatry*, vol. 11, 2020. https://doi.org/10.3389/fpsyt.2020.577429.

[19] Juárez-Rojop, I.E. *et al.* "Prevalence of Poor Sleep Quality and Associated Factors in Individuals with Rheumatoid Arthritis: A Cross-Sectional Study." *Medicina*, vol. 59, 2023. https://doi.org/10.3390/medicina59091633.

[20] Li, C. *et al.* "Association between Sleep Duration and Chronic Musculoskeletal Pain in US Adults: A Cross-Sectional Study." *Frontiers in Medicine*, vol. 11, 2024. https://doi.org/10.3389/fmed.2024.1461785.

## SUPPLEMENTARY TABLES

Supplementary Table S1: Final Analytic Sample Size (Overall and by Arthritis Type), NHANES 2015-2018

| Arthritis type | Unweighted n (%) |
|---|---|
| No arthritis | 6,597 (72.0) |
| Osteoarthritis | 1,098 (12.0) |
| Rheumatoid arthritis | 503 (5.5) |
| Psoriatic arthritis | 37 (0.4) |
| Unknown type | 925 (10.1) |
| Total | 9,160 (100.0) |

Supplementary Table S2: Survey-Weighted Logistic Regression Comparing OA vs. RA Among Participants with Arthritis, NHANES 2015-2018

| Predictor | aOR (95% CI) | p-value |
|---|---|---|
| **Arthritis Type (ref: Osteoarthritis)** | | |
| Rheumatoid arthritis | 1.04 (0.65-1.64) | 0.879 |
| **Age (Centered at Mean)** | | |
| Age (per year) | 0.97 (0.96-0.99) | 0.002 |
| Rheumatoid arthritis×age | 1.03 (1.01-1.06) | 0.021 |
| **Sex (ref: Female)** | | |
| Male | 1.77 (1.19-2.64) | 0.014 |
| **Race/Ethnicity (ref: Non-Hispanic White)** | | |
| Non-Hispanic Black | 2.06 (1.46-2.91) | 0.001 |
| Non-Hispanic Asian | 1.80 (1.10-2.94) | 0.034 |
| Other Hispanic | 1.74 (0.91-3.32) | 0.115 |
| Mexican American | 0.55 (0.32-0.94) | 0.048 |
| Other/Multiracial | 0.87 (0.42-1.83) | 0.726 |
| **Anthropometrics** | | |
| BMI (per kg/m²) | 1.03 (1.00-1.05) | 0.064 |
| **Smoking Status (ref: Never)** | | |
| Former | 0.74 (0.51-1.07) | 0.130 |
| Current | 1.01 (0.70-1.45) | 0.969 |
| **Education (ref: College Graduate/Above)** | | |
| Some college/AA | 1.64 (0.95-2.82) | 0.097 |
| HS graduate/GED | 1.42 (0.82-2.44) | 0.228 |
| Less than HS | 1.23 (0.73-2.07) | 0.456 |
| **Socioeconomic Status** | | |
| Poverty-income ratio (per unit) | 0.97 (0.85-1.11) | 0.662 |

Supplementary Table S3: Sex-Stratified Survey-Weighted Logistic Regression for Association Between Self-Reported Arthritis and Short Sleep Duration, NHANES 2015-2018

| Characteristic | Men, aOR (95% CI) | p-value | Women, aOR (95% CI) | p-value |
|---|---|---|---|---|
| **Arthritis Status** | | | | |
| Arthritis (Yes vs No) | 1.21 (0.92-1.59) | 0.188 | 1.04 (0.87-1.25) | 0.686 |
| **Age** | | | | |
| Age (years), centered at mean | 1.00 (1.00-1.01) | 0.255 | 1.01 (1.00-1.02) | 0.040 |
| Arthritis × age interaction | 0.98 (0.97-0.99) | 0.005 | 0.97 (0.96-0.99) | 0.001 |
| **Race/Ethnicity (Ref: Non-Hispanic White)** | | | | |
| Non-Hispanic Black | 1.83 (1.48-2.26) | <0.001 | 2.39 (1.86-3.07) | <0.001 |
| Non-Hispanic Asian | 1.04 (0.82-1.32) | 0.771 | 1.67 (1.29-2.17) | 0.002 |
| Other Hispanic | 1.54 (1.07-2.23) | 0.035 | 1.86 (1.41-2.46) | 0.001 |
| Mexican American | 1.17 (0.98-1.39) | 0.106 | 1.22 (0.92-1.62) | 0.180 |
| Other/Multiracial | 0.92 (0.64-1.34) | 0.671 | 1.21 (0.76-1.95) | 0.434 |
| **Body Mass Index** | | | | |
| BMI (kg/m²) | 1.01 (0.99-1.02) | 0.438 | 1.03 (1.01-1.04) | 0.001 |
| **Smoking Status (Ref: Never)** | | | | |
| Former | 0.94 (0.77-1.16) | 0.596 | 1.23 (0.97-1.55) | 0.102 |
| Current | 1.44 (1.18-1.75) | 0.002 | 1.67 (1.24-2.27) | 0.005 |
| **Education (Ref: College Graduate/Above)** | | | | |
| Some college/AA | 1.81 (1.39-2.36) | 0.001 | 1.29 (0.97-1.72) | 0.097 |
| HS graduate/GED | 1.91 (1.41-2.57) | 0.001 | 1.32 (0.92-1.91) | 0.156 |
| Less than HS | 1.60 (1.12-2.28) | 0.020 | 1.17 (0.77-1.76) | 0.476 |
| **Socioeconomic Status** | | | | |
| Poverty-income ratio (PIR) | 1.10 (1.04-1.17) | 0.008 | 1.04 (0.96-1.13) | 0.355 |