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Influence of sedentary behavior and physical activity in leisure and work on sleep duration: data from NHANES 2017–2018

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Abstract

Objective To evaluate the association between sedentary behavior (SB), moderate to vigorous physical activity (MVPA), and sleep duration.

Methods Data from the 2017–2018 National Health and Nutrition Examination Survey (NHANES) was analyzed. SB was assessed based on the average daily sitting time, while MVPA was estimated by the frequency and duration of leisure and work-related activities. The ratio of time spent in MVPA to time in SB was analyzed, and a thresholds of ≥ 1.0, 2.5 and 10 min of MVPA per sedentary hour was used to determine sufficiency for mitigating the effects of a sedentary lifestyle. Sleep duration was measured by the average hours slept on weekdays and weekends, classified according to National Sleep Foundation guidelines. The measures of SB, MVPA, and sleep were self-reported. Descriptive statistics were used to characterize the sample, and multivariate logistic regression was applied to assess the associations between movement behaviors and sleep duration.

Results The study included 5,533 participants, with 51.8% women, predominantly aged 26–64 years (66.1%). Insufficient physical activity was reported by 59.6% at work and 62.5% during leisure time. Recommended sleep duration was observed in 84.4% of the sample. Adjusted multivariate analysis revealed that individuals engaging in ≥ 2.5 min of MVPA during leisure-time for each sedentary hour were 38.9% less likely to experience short-term sleep (OR:0.72;95%CI:0.53–0.97). Conversely, those who performed the same amount of MVPA at work were 57.0% more likely to have short-term sleep (OR:1.57;95%CI:1.16–2.12).

Conclusion Meeting the MVPA threshold during leisure-time reduces the likelihood of short-term sleep, while higher MVPA levels at work increase the likelihood of short-term sleep.

Keywords Insomnia, Sedentary lifestyle, Physical activity, Short-term sleep, Intensity of physical activity

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Introduction

Sleep is a physiological state marked by altered consciousness, decreased sensitivity to external stimuli, and reduced respiratory rate, accompanied by characteristic motor and postural changes [1, 2]. Like diet and exercise, sleep significantly impacts various aspects of physical, cognitive, and emotional health [3].

Sleep quality is a complex concept that is difficult to measure objectively [3], encompassing various metrics such as total sleep time [4]. Five dimensions of sleep that seem most relevant for defining and measuring sleep health are sleep efficiency, timing, alertness, satisfaction and duration. For adults, 7 to 9 h of sleep are recommended [5]. Moreover, evidence suggests that going to bed earlier and maintaining regular, consistent sleep and wake times are beneficial to overall health. Sleep plays essential roles in various physiological processes, such as supporting immune function, conserving energy, and restoring brain function [6]. Furthermore, evidence highlights the association between adequate sleep duration and improved cognitive performance, including memory consolidation and problem-solving skills [7]. Other studies also suggest that both the timing and duration of sleep are critical for bone health, with insufficient or irregular sleep linked to impaired bone formation and increased fracture risk [8]. These findings underscore the importance of maintaining optimal sleep habits for overall health and well-being.

Sleep restriction being a known risk factor for adverse health outcomes, poor sleep quality has been linked to higher mortality rates and greater prevalence of diseases such as metabolic syndrome, diabetes, and hypertension [9]. Short sleep was linked to a significant increase in mortality as well as a higher risk of diabetes, cardiovascular disease, coronary heart disease, and obesity [10]. Also, there is evidence showing that insufficient sleep alters aspects of energy metabolism and behavior [11]. Therefore, it is crucial to identify and address the factors determining insufficient sleep [12].

Quality and duration of sleep are influenced by a complex interplay of factors, which can be broadly categorized into four groups: biological, environmental, personal/socioeconomic, and behavioral. Biological factors are inherent and generally stable, while environmental factors include exposure to light and noise. Behavioral factors, which offer substantial potential for intervention, include habits that can be modified through lifestyle changes, such as moderating alcohol and caffeine consumption, reducing sedentary behavior (SB), and promoting regular physical activity (PA). Unlike biological, environmental, and socioeconomic factors, which are often challenging to alter, behavioral factors are more malleable and can significantly impact sleep hygiene [13].

Psychological factors, such as anxiety, stress and depression, are some of the main ones that have a great influence on the sleep-wake cycle [14]. In addition to psychological factors, there are other well-known risk factors, such as gender, age [15, 16], excess weight [17] and also movement behaviors, such as PA [18], and SB, more recently [19]. Studies have shown that high levels of SB are associated with worse sleep quality and a higher prevalence of poor sleep quality [19]. On the other hand, regular practice of moderate to vigorous physical activity (MVPA), particularly during leisure time, has been associated with better sleep quality, including shorter sleep latency (time to fall asleep) and increased sleep duration [20].

The positive relationship between PA and health is well established, with higher levels of PA associated with better general health. Studies indicate that increasing regular PA reduces the risk of cardiovascular disease, type 2 diabetes and certain types of cancer, such as breast and colon cancer [21]. In addition, PA is associated with improved mental health, including reductions in anxiety, depression and stress symptoms [22]. It also contributes to more efficient body weight control and improved sleep quality [20]. These benefits cover multiple domains of physical and mental health, reinforcing the importance of promoting adequate levels of physical activity in different populations.

The context and nature of PA seems to play a significant role in its impact on sleep. It is crucial to distinguish between leisure-time physical activity (LTPA) and occupational physical activity (OPA), as their impacts on health are distinct. Evidence suggests that LTPA is associated with better sleep quality, psychological well-being and reduced risk of chronic diseases such as cardiovascular disease [23]. Because these activities are voluntary, they tend to be less stressful, allowing for adequate recovery. In contrast, OPA, which is often compulsory and performed in environments with high physical demand, can raise stress levels and compromise physical and mental recovery, leading to exhaustion, sleep disturbances and adverse health effects [24, 25].

With the shift in human lifestyles from nomadic to sedentary, SB has become widespread in various environments, including work, study, home, transportation, and even leisure, exacerbated by technological advances that reduce mobility [26]. Many of the factors that contribute to SB are difficult to change, especially when related to work and study. Traditionally, studies tend to assess PA and SB separately. However, the interaction between these two behaviors is fundamental for a more comprehensive understanding of how they affect sleep, as demonstrated by Menezes-Júnior, et al. 2023, in which regular leisure-time PA can mitigate the harmful effects of a sedentary lifestyle and improve general health, including sleep quality [19].

Given the challenges in reducing SB associated with work and academic demands, it is necessary to recommend some level of PA that can mitigate the effects of a sedentary lifestyle. Therefore, this study aims to evaluate the hypothesis that individuals with prolonged SB and lower levels of MVPA are more likely to experience sleep disturbances, while those with shorter periods of SB and higher levels of MVPA may have a protective effect.

Methodology

Study design and population

This cross-sectional study used population data from the National Center for Health Statistics (NHANES) survey from 2017 to 2018. The NHANES survey aims to assess the health and nutritional status of the United States of America (US) population and generate data for the world's largest public database. NHANES has been approved by the ethics committee, and details of its methodology and database are available at https://www.cdc.gov/nchs/nhanes/index.htm [27]

The initial sample consisted of 9,254 participants, but after applying exclusion criteria, 3,398 participants were removed because they were not in the 18–65 age group or older, 323 did not provide information on body mass index (BMI), PA or sleep-related variables, which were the variables of interest for this study. Thus, the study included a total of 5,533 participants for analysis, as shown in the flowchart (Fig. 1).

To ensure that the exclusion of individuals with missing data did not introduce significant biases, we carried out a differential loss analysis. The sociodemographic characteristics (age, gender, income and skin color) of the participants included in the study were compared with those who were excluded due to missing data on BMI, physical activity or sleep ($n=323$, 5.5% of the total number of individuals selected according to inclusion criteria). There were no significant differences in the characteristics analyzed between the samples ($p>0.05$), indicating that the loss of participants did not substantially affect the representativeness of the final sample. The detailed results of this analysis are presented in the supplementary material (Supplementary Table 1).

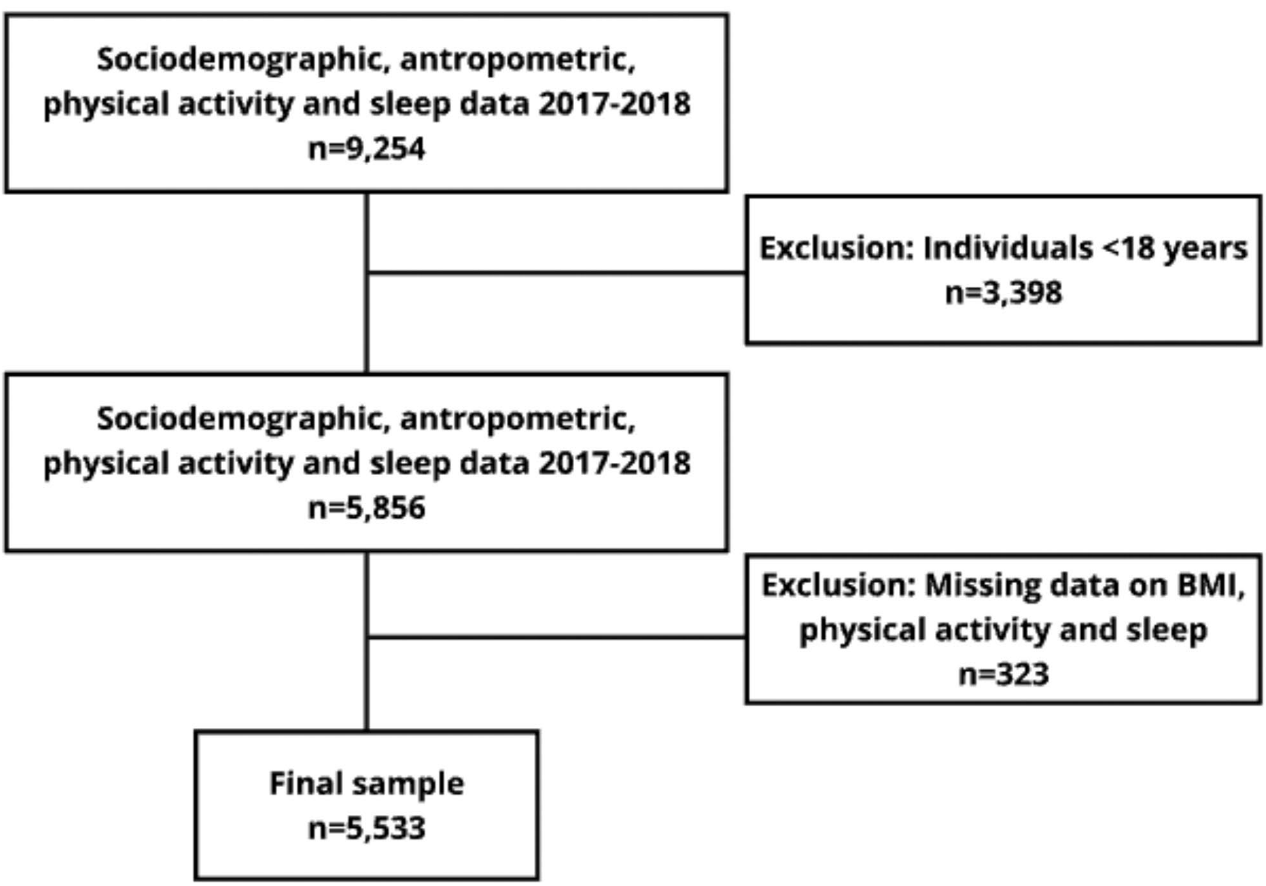

Fig. 1 – Flowchart of the eligible sample selection process

Sedentary behavior

The SB was assessed through a respondent-level interview using the Physical Activity and Physical Fitness questionnaire based on the Global Physical Activity Questionnaire (GPAQ) [27]. The aim of developing the GPAQ by the World Health Organization (WHO) was to create a tool that provides valid and reliable estimates of physical activity [28]. As a global instrument for measuring physical activity, the questionnaire has been translated into various languages and validated among adults in over 20 countries, demonstrating test-retest reliability from good to very good over periods of three days to two weeks. However, it seems that great care must be taken when interpreting the existing findings on GPAQ's concurrent validity [29].

The interview was also conducted at the MEC by trained interviewers using the CAPI system. The sedentary lifestyle was considered as time spent sitting, assessed using a question: "How much time do you usually spend sitting down on a typical day?". The reported sedentary time was recorded in minutes and then transformed into hours for later analysis.

Physical activity during leisure time and at work

PA during both leisure time and work was evaluated using questions from the Physical Activity and Physical Fitness questionnaire. To assess moderate PA during leisure time, participants were asked the following: "In a typical week, do you engage in any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate, such as brisk walking, cycling, swimming, or golf, for at least 10 minutes continuously?" They were also asked, "On how many days during a typical week do you engage in such activities?" and "How much time do you spend doing these activities on a typical day?" For vigorous activities, the questions were: "In a typical week, do you engage in any vigorous-intensity sports, fitness, or recreational activities that cause large increases in breathing or heart rate, such as running or basketball, for at least 10 minutes continuously?" followed by "On how many days during a typical week do you engage in these activities?" and "How much time do you spend doing these activities on a typical day?"

To assess moderate PA at work, participants were asked: "Does your job involve moderate-intensity activity that causes small increases in breathing or heart rate, such as brisk walking or carrying light loads for at least 10 minutes continuously?". They were further asked, "On how many days during a typical week do you engage in such activities as part of your work?" and "How much time do you spend doing these activities on a typical day?" For vigorous work-related activity, participants were asked: "Does your job involve vigorous-intensity activity that causes large increases in breathing or heart rate, such as carrying or lifting heavy loads, digging, or construction work for at least 10 minutes continuously?" followed by "On how many days during a typical week do you engage in these activities as part of your job?" and "How much time do you spend doing these activities on a typical day?"

The intensities of these activities were combined to create a new variable, MVPA. To estimate the average daily activity time, the number of active days per week was multiplied by the daily duration of activity and then divided by 7 [10]. Additionally, a ratio was calculated between the time spent in PA (both during leisure and work, in minutes per day) and time spent in SB (in hours per day). Subsequent classification followed the method suggested by Chastin et al. (2021) [30], with a cut-off point of 2.5 min of activity per sedentary hour to mitigate the impact of SB.

Sleep

Sleep duration was assessed using a standardized approach, where participants answered specific questions about the amount of sleep they got during the night. The questions included: 'How many hours of sleep do you get on average during the night on weekdays?' and 'How many hours of sleep do you get on average during the night on weekends?'. The answers were used to calculate the average number of hours of sleep per night, combining weekdays and weekends. Sleep was classified according to the sleep duration recommendations of the National Sleep Foundation [5]. The population was divided into two groups: young adults aged 18 to 25 and adults aged 26 to 64. For people aged between 18 and 25, 7 to 9 h of sleep are recommended for optimal health, while 6 h and 10 to 11 h are considered reasonable. For people between the ages of 25 and 64, the recommendation range is the same, but 6 and 10 h can be reasonable, and 6 and more than 10 h are not recommended.

Covariates

Demographic, anthropometric and clinical covariates were collected using standardized methods, ensuring the accuracy and comparability of the data. The inclusion of these covariates was essential to control for possible confounders in the multivariate analysis, given that different demographic, socioeconomic and health factors can influence both physical behavior and sleep.

Sex, self-reported as female or male, and age, categorized into three groups (18–25 years, 26–64 years, and 65 years or older), were included to adjust for the impact of these variables on the outcomes analyzed. It is known that age directly affects sleep patterns and the propensity to practice physical activity, and gender can also influence differences in health behaviors.

Ethnicity, self-reported according to the NHANES categories, included Hispanics (Mexican-Americans and other Hispanics) and non-Hispanics (whites, blacks and multiracials). Ethnicity was considered an important covariate, since racial and ethnic differences can affect sleep quality and physical activity levels. Ethnic minority individuals, especially blacks and Hispanics, tend to report more sleep problems and lower levels of physical activity, often associated with discrimination and barriers to accessing health care [31, 32].

Socioeconomic status (SES) was measured by the family income index in relation to the poverty line. Income was categorized as low, medium and high, based on the poverty index. This variable was included because income can limit access to places for physical activity, thus influencing activity levels and sleep patterns. Studies show that low-income individuals often face greater physical inactivity and poorer sleep quality [33].

Body Mass Index (BMI), calculated from weight and height measurements taken by trained professionals, was categorized as non-obesity (BMI < 30 kg/m²) and obesity (BMI ≥ 30 kg/m²). BMI is relevant because obesity is associated with both lower levels of physical activity and a higher prevalence of sleep disorders, such as sleep apnea and insomnia [34]. Regular physical activity is recommended for weight control and maintaining metabolic health, helping to prevent obesity.

Medical conditions diagnosed by a healthcare professional were also included in the model as covariates. These conditions included asthma, arthritis, gout, congestive heart failure, cardiovascular disease, myocardial infarction, emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), and cancer. These conditions were identified through self-reported diagnosis questions in the NHANES medical conditions questionnaire. In addition to these main variables, data was included on the use of medication related to diabetes, hypertension, cardiovascular diseases, sleep disorders and pain, identified by ICD-10 codes, and grouped as follows: Diabetes (E10, E10.4, E11, E11.2, E11.2P, E11.4, E11.8, E11.P), cardiovascular diseases (I20.9, I21, I21.P, I25.9, I48.9, I49.9, I50.9, I51.9, I51.9P, I63, I63.P, I70, I70.P, I10, I10.P), sleep disorders (G47.0, G47.9), pain (R51, R52), chronic kidney disease (J06.9, J98.9, R09.8), and mental health (F41.0, F41.9, F32.9, F33.9). Medication can influence both sleep and physical activity levels, and it is important to adjust for these variables to avoid bias in the analysis. Similarly, self-reported medical conditions (such as asthma, arthritis, heart failure, lung disease and cancer) were included as covariates, since these health problems can directly impact physical activity patterns and sleep duration.

Furthermore, caffeine consumption was assessed based on 24-hour dietary recalls, since caffeine intake can alter sleep patterns [35]. NHANES collects two 24-hour dietary recall interviews for all participants, one in-person and one via telephone, with a 3–10 day interval between them. The average daily caffeine intake (mg/day) was calculated from these recalls.

Statistical analysis

The statistical analysis was meticulously conducted in accordance with the guidelines of the Centers for Disease Control and Prevention (CDC), utilizing data from NHANES 2017–2018. Analyses were performed using Stata statistical software, version 18.0, with a significance level of 5%. The Stata syntax incorporated the 'svy' prefix, which accounts for sample weights, stratification, and clustering inherent in the NHANES complex sampling design, thereby allowing results to be generalized to the U.S. population. Initially, the sample was characterized using absolute and relative frequencies for categorical variables and measures of central tendency and dispersion for continuous variables. The commands 'svy: tabulate' were used to organize categorical variables, and 'svy: mean' was applied to continuous variables, generating tables with 95% confidence intervals and conducting Pearson's chi-squared tests to assess associations. The logistic regressions were conducted using 'svy: logistic', ensuring that the results were generalizable to the US population.

To explore the relationships between movement behaviors and sleep duration, multivariate logistic regression analysis was applied. The adjusted model estimated odds ratios (OR) and confidence intervals (CI) to determine whether the ratio of MVPA to SB could predict adequate sleep duration. Both leisure-time physical activity (LTPA) and occupation physical activity (OPA) were included in the model, ensuring that when LTPA was analyzed, it was adjusted for OPA, and vice versa. This approach acknowledges the fixed nature of time within a 24-hour day, where increased engagement in one behavior (e.g., MVPA) results in a reduction in others (e.g., SB or sleep), thus minimizing bias. The adjusted model estimated odds ratios (OR) and confidence intervals (CI) to determine whether the ratio of MVPA to SB could predict adequate sleep duration. Both LTPA and OPA were included simultaneously in the model, such that LTPA was adjusted for OPA, and vice versa. This adjustment helps account for the potential confounding effects between different types of physical activity and their impact on sleep duration.

In constructing the multivariate model, careful selection of variables was based on prior knowledge and causal inference. Sociodemographic, economic, and behavioral variables were considered for adjustment, given their potential influence as confounding factors. Consequently, the multivariate model was adjusted for sex, age group, ethnicity, income, BMI, caffeine consumption, medical diagnoses (asthma, arthritis, gout, congestive heart failure, cardiovascular disease, myocardial infarction, emphysema, bronchitis, COPD, cancer), and the use of medications related to diabetes, hypertension, cardiovascular diseases, sleep disorders, pain, chronic kidney disease, and mental health conditions. These adjustments were made to account for potential confounding factors that could bias the observed associations. These variables were considered confounders because they are known to impact both the exposure (physical activity and sedentary behavior) and the outcome (sleep duration) through various health-related mechanisms. For example, conditions like cardiovascular disease and diabetes can limit physical activity levels, while sleep disorders and mental health conditions directly influence sleep patterns. Additionally, medication use, such as for pain or sleep disorders, can alter both physical activity and sleep outcomes, contributing to potential confounding. A detailed rationale for the inclusion of each variable in the model, including their pathways and potential influence on the relationships studied, is provided in the supplementary material: 'Supplementary Table 2: Health-related pathways overview illustrated in the confounding models'. The Akaike Information Criterion (AIC) was then used to optimize the model's fit by balancing model complexity and accuracy. While the selection of variables to include in the model was guided by prior research and the literature (as outlined in the article), the determination of the most appropriate form of each variable (e.g., continuous, categorical, or using specific thresholds) was made based on AIC values. For each variable, we tested different forms and configurations, selecting the one with the lowest AIC to ensure the best-fitting model. This iterative process allowed us to refine the model, minimizing AIC to achieve both an accurate and parsimonious model.

Furthermore, the models were also evaluated according to age, gender and SES strata. This stratification was carried out to identify possible variations in the association between MVPA per SB and sleep duration, considering different population subgroups.

Results

The sample consisted of 51.8% females, with 66.1% of participants aged between 26 and 64 years, representing a diverse range of ethnicities. A significant portion of the sample (73.4%) reported an income of less than 5 dollars per hour. Regarding nutritional status, 57.4% of the participants had a BMI below 30, classifying them as non-obese. The characteristics of the sample are shown in Table 1.

The participants reported an average sleep of 7.94 h per day (95%CI:7.3–7.5), and according to the categories of recommended sleep duration by age group, 86.9% (95%CI:84.6–89.8) of the population had a sleep duration classified as either recommended or acceptable, while 13.1% had an inadequate sleep duration (Fig. 2). In terms of movement behaviors, the participants had an average SB of 8.94 h per day (95%CI:8.61–9.09), while the practice of MVPA, measured in minutes per day, averaged 88.49 min (95%CI:77.90-99.39) at work and 23.62 min (95%CI:21.85–25.43) at leisure (Fig. 3). In the combined analysis, 59.6% and 62.5% demonstrated insufficient activity levels per hour of SB at work and during leisure time, respectively (Table 1).

Furthermore, Table 1 presents a statistically significant association between age group and sleep duration (X^2=182.2889, $p<0.001$). Significant associations were also found with race/ethnicity (X^2=57.3333, $p<0.001$), income (X^2=37.2340, $p<0.001$), and leisure-related PA (X^2=27.7697, $p=0.0028$). However, no significant associations were observed between sleep duration and other variables analyzed: gender (X^2=7.2829, $p=0.3959$), obesity (X^2=6.8617, $p=0.187$), and work-related PA (X^2 =4.3836, $p=0.4048$).

In the multivariate model, the cut-off points proposed in the literature for leisure-time physical activity showed that individuals who accumulated at least 1 min of MVPA per hour of SB during leisure time had a 40.8% lower chance of short sleep duration (OR: 0.71; 95%CI: 0.51–0.98; $p=0.038$). For those who performed 2.5 min of MVPA per hour of SB during leisure time, the chance of short sleep duration was 38.9% lower (OR: 0.72; 95%CI: 0.53–0.97; $p=0.033$). However, when considering 10 min of MVPA per hour of SB there was no significant difference (OR:0.83; 95%CI: 0.55–1.26; $p=0.366$). In contrast, considering the practice of physical activity in the workplace, there was a 57% and 65% increase in the chance of short sleep duration, respectively for individuals who accumulated at least 2.5–10 min of MVPA per hour of SB during work (≥2.5 MVPA/SB; OR: 1.57; 95%CI: 1.16–2.12; $p=0.006$; ≥ 10.0 MVPA/SB; OR: 1.65; 95%CI: 1.23–2.22; $p=0.003$) (Table 2).

When the analysis was based on the tertiles of data distribution, it was observed that individuals in the highest tercile of MVPA at leisure (tercile 3), who practiced at least 3.33 min of MVPA at leisure per hour of SB, showed a 38.9% reduction in the chance of short sleep duration (OR: 0.72; 95%CI: 0.53–0.97; $p=0.034$). Those in the highest tertile of MVPA at work who practiced at least 7.5 min of MVPA at leisure per hour of SB showed a 44% increase in the odds of short sleep duration (OR: 1.44; 95%CI: 1.09–1.91; $p=0.014$) (Table 3).

We also evaluated how the results behaved when stratifying by characteristics such as age, gender, and SES. The results for the 26–64 age group followed the same pattern as the general non-stratified model. However, among younger and older individuals, there was no significant association between MVPA/SB and sleep. For

Table 1 Sociodemographic characterization, lifestyle and its relationship with sleep time in the population, NHANES 2017 – 201

Variables	Total	Sleep duration			
		Optimal	Reasonable	Not recommended	*p*-value
Sex					
Male	48.2 (46.3–50.0)	46.7 (43.8–49.7)	50.1 (44.8–55.4)	51.0 (43.7–58.3)	0.395
Female	51.8 (50.0–53.7)	53.3 (50.3–56.2)	49.9 (44.6–55.2)	49.0 (41.7–56.3)	
Age (years)					
18–25	14.4 (12.3–16.7)	15.2 (13.1–15.5)	15.3 (12.4–18.8)	8.5 (5.7–12.6)	**< 0.001**
26–65	66.1 (63.1–68.9)	70.7 (67.7–73.6)	57.2 (53.2–61.1)	62.1 (54.5–69.2)	
≥65	19.6 (17.0– 22.4)	14.1 (12.0–16.5)	27.5 (23.5–31.8)	29.3 (22.5–37.3)	
Income					
Poverty (< 5 dollars/hour)	73.4 (70.0–76.8)	71.3 (67.4–75.0)	73.4 (68.2–78.0)	83.3 (76.5–88.4)	**0.002**
No poverty (≥ 5 dollars/hour)	26.6 (23.2–30.3)	28.7 (25.0–32.6)	26.6 (22.0–31.8)	16.7 (12.0–23.5)	
Obesity					
Not obese (< 30 Kg/m^2)	57.4 (53.5–61.1)	58.1 (54.0–62.0)	58.1 (37.0–47.3)	52.9 (47–52.1)	0.187
Obesity (≥ 30 Kg/m^2)	42.6 (39.0–46.5)	41.9 (38.0–46.0)	41.9 (37.0–47.3)	47.1 (41.0–53.4)	
Ethnicity					
Mexican-American	9.1 (6.1–13.5)	9.5 (6.5–14.0)	8.4 (5.1–14.0)	8.6 (5.3–14.0)	**< 0.001**
Other Hispanics	7.0 (5.2–8.8)	6.8 (5.2–8.8)	7.5 (5.3–10.5)	7.2 (5.6–9.2)	
Non-Hispanic white	62.0 (56.5–67.2)	62.8 (56.9–68.3)	63.0 (57.1–68.5)	56.5 (50.0–64.0)	
Non-Hispanic black	11.3 (8.32–15.2)	9.4 (6.7–13.1)	12.0 (8.7–16.4)	18.5 (14.2–24.0)	
Other races - multiracial	10.5 (8.2–13.5)	11.5 (8.5–15.3)	9.1 (7.0–15.3)	9.1 (7.0–12.0)	
Sedentary behavior (SB)					
< 9 h/day	80.2 (78.2–82.1)	79.1 (76.0-81.9)	81.3 (76.7–85.1)	82.9 (78.9–86.3)	0.323
≥ 9 h/day	19.8 (17.9–21.8)	20.9 (18.1–24.0)	18.7 (14.9–23.3)	17.1 (13.7–21.1)	
Leisure-time physical activity per SB					
<2.5 min/hour	57.1 (53.4–60.3)	55.4 (52.4–58.7)	56.4 (52.0–60.7)	66.2 (59.1–72.6)	
≥2.5 min/hour	42.9 (39.7–46.3)	44.6 (41.3–47.9)	43.6 (39.3–48.1)	33.8 (27.4–40.9)	**0.002**
Physical activity at work per SB					
<2.5 min/hour	54.1 (50.9–57.2)	54.6 (50.5–58.5)	54.8 (49.7–59.7)	50.4 (48.8–56.0)	0.405
≥2.5 min/hour	45.9 (42.8–49.1)	45.4 (41.5–49.5)	45.2 (40.3–50.3)	49.6 (44.0–55.2)	

*Chi-square test for the association between the study's categorized variables and sleep time. A value of $p < 0.005$ was considered significant.

gender, men showed similar results to the overall group, with a significant association between leisure-time physical activity and a lower chance of short sleep duration. In women, the protective effect was restricted to leisure-time physical activity, following the same pattern of association observed in the general model. As for SES, there were important variations. In individuals with low SES, more leisure-time MVPA per hour of SB was protective for sleep, while occupational MVPA showed no significant association. In contrast, for individuals with

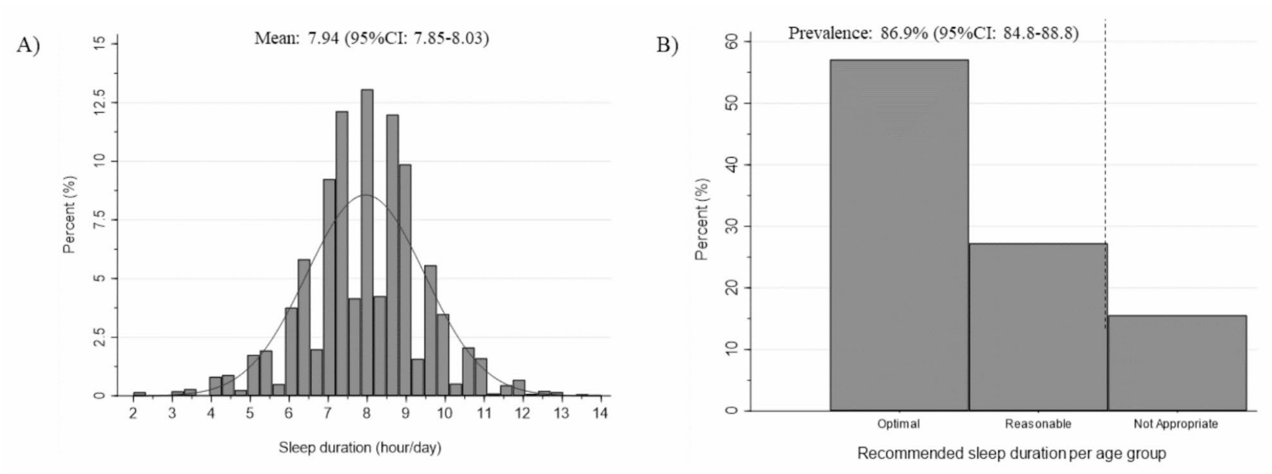

Fig. 2 Distribution of sleep duration and prevalence of recommended sleep duration, NHANES 2017–2018
Legend: (**A**) Distribution of sleep duration averaged 7.94 h per day (95% CI: 7.3–7.5). (**B**) Histogram of the distribution of sleep duration in adults according to age group categories

medium SES, MVPA during leisure time was not associated with sleep, but MVPA in the workplace was a risk factor, as observed in the general model. In the high SES group, no significant associations were found in any of the physical activity categories. These results are detailed in the Supplementary Tables (Tables S3, S4 and S5).

Discussion

The results of this study support the initial hypothesis that practicing MVPA during leisure time, even when associated with SB at work, is associated with a lower probability of having a short sleep duration. On the other hand, MVPA performed in the work context was negatively associated with sleep duration. These results emphasize the importance of considering the context in which PA takes place, as it has different effects on sleep depending on whether it is performed during leisure time or occupationally. Sleep is a vital physiological process, and the prevalence of short sleep duration observed in our study, where 13.1% of participants did not reach the recommended sleep duration, highlights the importance of understanding the factors that contribute to this condition.

In our results, participants who practiced at least 2.5 min of MVPA during free time for every hour of SB were 37% less likely to have a short sleep duration (OR: 0.73; 95%CI: 0.56–0.96; p-value = 0.027). This result is similar to that found in other studies, such as that presented by Menezes-Júnior et al. 2023, where, evaluating the cut-off point suggested in the literature, the chance of poor sleep quality was 3 times lower in individuals who performed 2.5 min or more of leisure-time MVPA per hour of SB compared to individuals who performed less than 2.5 min of MVPA per hour of SB (OR: 0.33; 95%CI: 0.16–0.72)11,23 also found similar results with the mental health outcome. Young adults who did not practice 2.5 min of MVPA per hour of SB had a higher chance of anxiety symptoms (OR:1.44;95%CI:1.31–1.58) and depression (OR:1.74;95%CI:1.59–1.92)23.

It is important to note that although the study by Menezes-Júnior et al. (2023) also used self-reported data, there were important differences in the methodologies adopted [36]. While both studies assessed sedentary behavior using questionnaires, Menezes-Júnior et al. (2023) used VIGITEL to assess leisure-time physical activity, a specific tool for surveillance in the Brazilian context, which differs from the physical activity protocol used in our study, based on NHANES. In addition, sleep quality was measured in Menezes-Júnior's study using the Pittsburgh Sleep Quality Index (PSQI), a validated instrument that was not used in our study. These methodological differences limit the direct comparability of the results, especially about the relationship between physical activity, sedentary behavior, and sleep quality. However, both studies share the limitation of relying on self-reported data, which can introduce biases related to individual perception and reporting accuracy.

Despite the protective results of higher MVPA at leisure for sleep duration, our study found opposite results when evaluating OPA. Individuals who reported the same level of occupational MVPA hours were 1.33 times more likely to have short sleep duration (OR: 1.33; 95%CI: 1.06–1.67; p-value = 0.019). The differential impact of MVPA at leisure versus OPA on sleep underscores the importance of the context in which PA occurs. MVPA at leisure is often self-directed, performed in less stressful environments, and can be associated with relaxation and fun, which can promote better sleep quality [37].

In addition, MVPA at leisure helps regulate circadian rhythms, improves mood, and reduces stress levels,

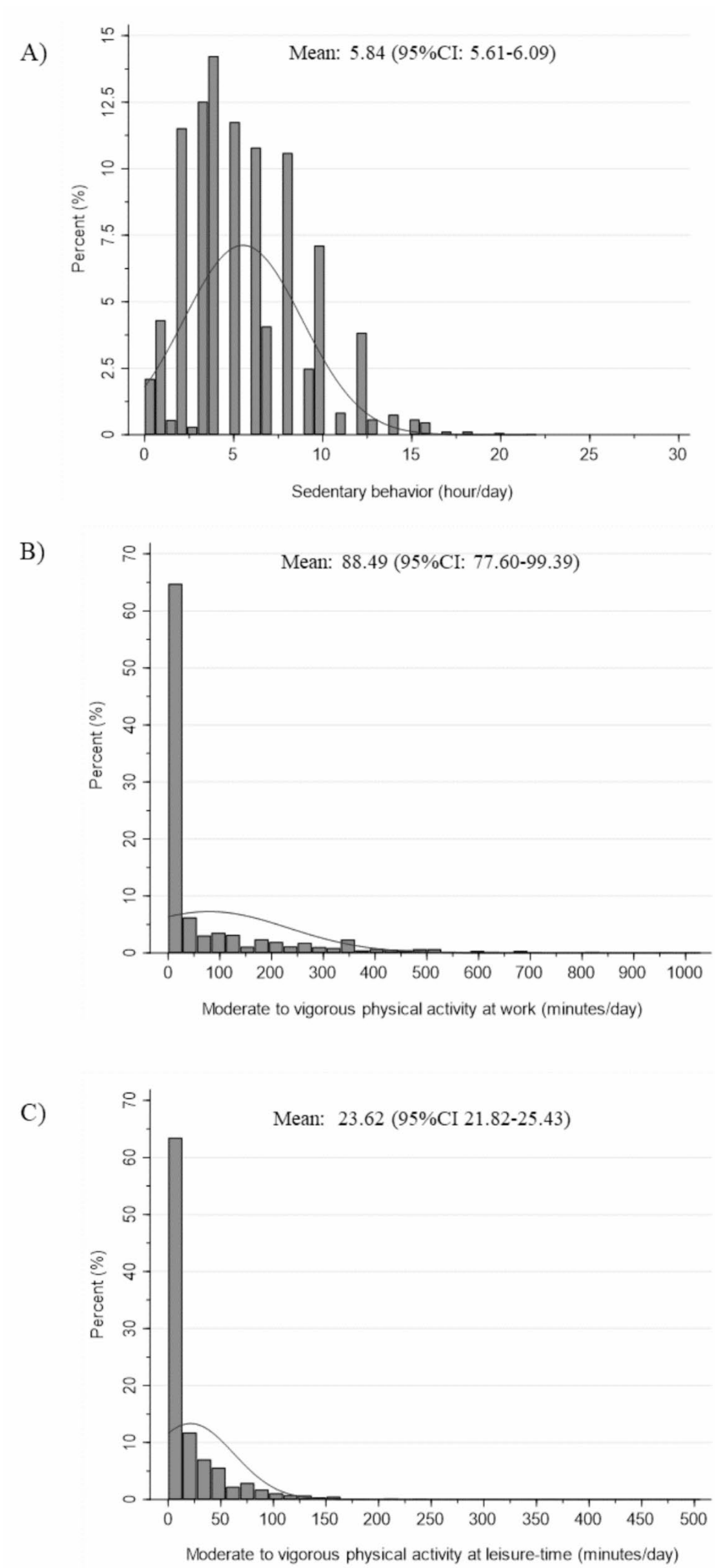

Fig. 3 Distribution of movement behaviors of adults, NHANES 2017–2018
Legend: Distribution of movement behaviors of adults, showing (**A**) the histogram of time spent in sedentary behavior (hours/day), (**B**) the histogram of time spent in moderate to vigorous physical activity at work (minutes/day), (**C**) the histogram of time spent in moderate to vigorous physical activity at leisure-time (minutes/day)

Table 2 Association between sleep duration and moderate to vigorous leisure-time physical activity for each hour in sedentary behavior, according to the domain of physical activity, using cut-off points proposed in the literature, NHANES 2017–2018

Association with short-sleep duration*	Univariate			Multivariate		
	OR	95%CI	*p*-value	OR	95%CI	*p*-value
Leisure-time physical activity						
< 1.0 min of MVPA per hour of SB	1.00	-	-	1.00	-	-
≥ 1.0 min of MVPA per hour of SB	0.63	0.51–0.79	**0.001**	0.71	0.51–0.98	**0.038**
< 2,5 min of MVPA per hour of SB	1.00	-	-	1.00	-	-
≥ 2,5 min of MVPA per hour of SB	0.64	0.51–0.81	**0.001**	0.72	0.53–0.97	**0.033**
< 10.0 min of MVPA per hour of SB	1.00	-	-	1.00	-	-
≥ 10.0 min of MVPA per hour of SB	0.82	0.57–1.17	0.257	0.83	0.55–1.26	0.366
Physical activity at work						
< 1.0 min of MVPA per hour of SB	1.00	-	-	1.00	-	-
≥ 1.0 min of MVPA per hour of SB	1.09	0.83–1.43	0.522	1.40	0.98–1.99	0.063
< 2,5 min of MVPA per hour of SB	1.00	-	-	1.00	-	-
≥ 2,5 min of MVPA per hour of SB	1.18	0.91–1.55	0.198	1.57	1.16–2.12	**0.006**
< 10.0 min of MVPA per hour of SB	1.00	-	-	1.00	-	-
≥ 10.0 min of MVPA per hour of SB	1.27	0.95–1.69	0.098	1.65	1.23–2.22	**0.003**

MVPA: Moderate to vigorous leisure-time physical activity. SB: Sedentary behavior. OR: Odds ratio; CI: Confidence interval.

The ratio MVPA/SB was calculated by dividing the minutes of moderate to vigorous leisure-time physical activity (MVPA) per day by the hours of sedentary behavior (SB) per day.

We performed sensitivity analyses using different thresholds of moderate to vigorous physical activity (MVPA), including 1 min of MVPA per hour of sedentary behavior (SB), 2.5 min of MVPA per hour of SB, and 10 min of MVPA per hour of SB, as suggested by Chastin et al. (2021).

*Multivariate logistic regression adjusted for sex, age group, ethnicity, income, body mass index, caffeine consumption, medical diagnoses of chronic diseases, use of medications, and both SB and physical activity during leisure and work hours.

Values in bold indicates statistical significance (p-value < 0.05).

Table 3 Association between sleep duration and moderate to vigorous physical activity during leisure time per hour of sedentary behavior, using tertiles of distribution based on study data, NHANES 2017–2018

Association with short-sleep duration*	Variation (MVPA/SB)	Univariate			Multivariate		
		OR	95%CI	*p*-value	OR	95%CI	*p*-value
Leisure-time physical activity							
Tertile 1	0.0 min MVPA/ h SB	1.00	-	-	1.00	-	-
Tertile 2	0.14–3.33 min MVPA/ h SB	0.66	0.46–0.95	**0.028**	0.81	0.58–1.12	0.191
Tertile 3	> 3.33 min MVPA/ h SB	0.65	0.51–0.82	**0.001**	0.72	0.53–0.97	**0.034**
Physical activity at work							
Tertile 1	0.0 min MVPA/ h SB	1.00	-	-	1.00	-	-
Tertile 2	0.12–7.50 min MVPA/ h SB	0.73	0.46–1.15	0.162	0.76	0.48–1.22	0.256
Tertile 3	> 7.50 min MVPA/ h SB	1.18	0.89–1.57	0.231	1.44	1.09–1.91	**0.014**

MVPA: Moderate to vigorous leisure-time physical activity. SB: Sedentary behavior. OR: Odds ratio; CI: Confidence interval.

The ratio MVPA/SB was calculated by dividing the minutes of moderate to vigorous leisure-time physical activity (MVPA) per day by the hours of sedentary behavior (SB) per day.

We performed analyses using tertiles of distribution of the study data.

*Multivariate logistic regression adjusted for sex, age group, ethnicity, income, body mass index, caffeine consumption, medical diagnoses of chronic diseases, use of medications, and both SB and physical activity during leisure and work hours.

Values in bold indicates statistical significance (p-value < 0.05).

which contributes to better sleep quality [38, 39]. Physiologically, MVPA at leisure can help reduce muscle tension and lower cortisol levels, both of which lead to better sleep [40]. Socially and culturally, MVPA at leisure is often seen as a form of self-care [41], which may reinforce its positive effects on sleep.

MVPA performed during working hours was negatively associated with sleep duration. This negative relationship may stem from the physical and psychological demands associated with work, which can lead to increased stress and fatigue, negatively affecting sleep [42]. For example, in highly stressful work environments such as hospitals, more than half of workers report sleep difficulties, a situation that can be exacerbated by the physically demanding nature of their work [43]. OPA is often seen as a mandatory task, which can increase stress and reduce recovery time, explaining the observed negative effects on sleep [33]. These adverse effects of OPA can be minimized by implementing practices that reduce physical and mental stress, such as regular breaks during work, wellness programs that encourage both physical and psychological well-being, and adjustable workstations that allow for alternation between sitting and standing when possible [43]. Specific adaptations for different groups of workers include the use of personalized ergonomics, such as breaks based on physical loads or meditation and stretching practices in the workplace, which have been effective in promoting greater physical and mental balance, reducing the negative effects of OPA, and promoting general health [33, 44].

The physiological stress of work-related PA, such as elevated heart rate and persistent muscle tension, can impair the body's ability to make the transition to restful sleep [45]. Few studies have explored the association between OPA and sleep disorders. Research indicates that physically demanding jobs are often associated with sleep problems, while moderate to high levels of OPA have been associated with reduced sleep duration and quality [17]. These findings suggest that the nature and context of OPA warrant further investigation to better understand its impact on sleep.

For example, OPA increases the risk of myocardial infarction and is related to prolonged sick leave [46]. As already discussed, long periods of OPA can cause stress and fatigue, consequently deviations from optimal sleep duration, elevated blood pressure, and heart rate due to muscle contractions during heavy lifting or static postures in manual labor. Although MVPA at leisure also involves heavy lifting (in some cases), it is generally shorter and controlled/monitored by qualified professionals. About gender, OPA associated with sleep quality can behave differently, since men and women have different physiological responses. Women tend to report greater exhaustion and psychosocial stress than men [47].

The difference in PA during leisure-time and occupational on sleep also has significant implications for public health interventions and policies. Encouraging PA during leisure time while addressing the negative impacts of OPA can be an effective strategy for improving sleep quality and overall health. While encouraging PA during leisure time is beneficial for sleep quality, addressing the negative impacts of OPA presents a considerable challenge. This challenge is particularly complex due to the intertwining of socio-cultural and economic factors.

Individuals in lower socio-economic positions often have jobs that are physically demanding but offer little flexibility or support for recovery, exacerbating sleep problems. These workers may not have access to resources that promote restful sleep, such as sufficient free time, stress management programs, or ergonomic adjustments to reduce physical effort [33, 48].

About the analysis of data stratified by gender, age group, and SES, we found that among women, there was a protective effect for leisure-time physical activity, following the same pattern of association observed in the general model and men showed similar results to the general group, with a significant association between MVPA at leisure and a lower probability of short sleep duration. These data are in line with the literature, as shown in the study by Zinc, et al., 2024, in which they point out that puberty marks the beginning of the differentiation between sleep quality and physical activity between the sexes [33]. Women become more active and make less use of screens than men, so they have less sedentary behavior. Another study highlights that although women tend to sleep better, they report more sleep problems than men of a similar [48].

In our study, there was no significant association between AFMV/SB and sleep in older individuals. According to Helfrich, et al., 2018 and Scullin (2012), aging is directly related to shorter sleep time and added to longer sleep latency and altered sleep quality [49, 50].

Improving the quality of sleep for these individuals requires comprehensive strategies that go beyond simply promoting PA. Policy-level interventions are needed that address the broader social determinants of health, ensuring equitable access to sleep-promoting environments and practices [51]. Future research should focus on identifying specific interventions that not only improve sleep quality by considering these contextual factors but also address the underlying sociocultural and economic disparities that contribute to poor sleep outcomes in physically demanding occupations.

This study benefits from a large and diverse sample from NHANES 2017–2018, providing broad generalizability across various demographic groups. It comprehensively assesses movement behaviors by examining both SB and occupational MVPA and leisure, using an innovative ratio of MVPA to SB that offers new insights into mitigating the effects of sedentary lifestyles.

In this sense, it is worth recognizing the interdependence of movement behaviors within a 24-hour cycle, as highlighted in the literature on time allocation and its effects on health [52]. When an individual increases the amount of time dedicated to moderate to vigorous physical activity (MVPA), whether at leisure or work, there is a proportional decrease in the time available for other activities, such as sedentary behavior (SB) or sleep [52]. This interconnection was properly addressed in our multivariate models, in which we adjusted the analyses considering all waking behaviors (MVPA and SB), thus minimizing possible biases that arise when treating these behaviors in isolation [53]. From this perspective, it is possible to suggest that changes in physical activity behaviors can have a direct impact on sleep duration, either positively or negatively, depending on how time is redistributed [54]. This finding is particularly relevant for interventions that seek to improve both physical activity levels and sleep quality and quantity since such interventions need to consider the natural trade-offs between these behaviors within the same daily cycle.

Results stratified by sex, age, and socioeconomic status (SES) revealed important differences in the associations between physical activity (PA), sedentary behavior (SB), and sleep duration. These variations are consistent with the literature and reflect the distinct roles that biological, behavioral, and contextual factors play in population subgroups.

Concerning gender, our findings indicate that, among men, leisure-time PA had a protective association with a lower probability of short sleep duration, mirroring the results of the general model. Among women, this association was observed similarly, with leisure-time physical activity having a positive effect on sleep, but with greater prominence. These results are consistent with the literature that points to sex differences in the impact of PA on sleep, with studies showing that during puberty there is a differentiation in physical activity behavior and screen use between the sexes. In women, there is a tendency towards greater engagement in PA and less sedentary behavior, which may explain the more positive relationship with sleep quality [33]. However, even with this advantage, women tend to report more sleep problems than men of a similar age, probably due to greater sensitivity to emotional and hormonal disturbances, as reported in studies by Bisson and Lachman (2023) [48].

About age, we found that in younger (under 26) and older (over 64) individuals, there was no significant association between PA/GS and sleep. This finding can be explained by biological factors that affect sleep quality at different stages of life. In younger people, the contemporary lifestyle, marked by high levels of exposure to electronic devices and irregular sleep schedules, can attenuate the benefits of PA on sleep [5]. In older people, sleep fragmentation and lower sleep efficiency associated with ageing can reduce the ability of PA to improve sleep duration [49, 50]. In addition, the decrease in PA with advancing age may also contribute to this lack of association.

About socioeconomic status (SES), our results show interesting variations. In low SES individuals, leisure-time PA had a protective effect on sleep duration, while PA at work was not significantly associated with sleep. This finding reflects the fact that individuals with lower SES generally have more physically demanding jobs and less time for leisure-time PA, which can compromise the benefits of PA on sleep. On the other hand, for medium SES individuals, PA at work was shown to be a risk factor for sleep problems, suggesting that the nature of PA at work (often repetitive and stressful) may be associated with greater fatigue and less recovery, negatively impacting sleep [55]. In the high SES group, we found no significant associations between PA categories and sleep, possibly due to factors such as greater control over work and leisure schedules, as well as better living conditions and access to health care, which can buffer the negative effects of intense PA [56].

These findings underline the importance of tailoring public health interventions to specific population subgroups, taking into account the socio-demographic, contextual, and behavioral characteristics that shape the relationships between PA, SB, and sleep health.

The contextual differentiation between work and leisure activity adds valuable depth to the findings. One of the main limiting aspects of this study is the use of self-reported data to measure levels of physical activity and sedentary behavior, compared to the objective accelerometry data used in studies such as that by Chastin et al. (2015) [57]. Although accelerometers provide more objective and accurate measurements of the frequency, intensity, and duration of physical activity, questionnaires are subject to memory and socially desirable response biases, which can result in underestimation or overestimation of physical activity levels [58]. This difference between the two methods can affect the comparability of the results.

Furthermore, due to the lack of studies suggesting specific cut-off points for self-reported data, we used thresholds based on accelerometry data as a reference to ensure comparability with the literature, as well as performing additional analyses based on the quintiles of the data distribution in our study. However, this approach may not fully capture the complexity of the behaviors measured through self-report.

This study used data only from the 2017–2018 NHANES cycle, which is a limitation. Although this approach allowed for an analysis focused on a pre-pandemic period of COVID-19, we did not capture temporal variations that could have been observed over previous cycles. In addition, the sleep-related variables essential to our study (sld012 and sld013) were only included in NHANES from 2017 onwards, limiting the possibility of integrating older cycles. The choice of this cycle was also based on the consistent way in which the variables of physical activity during leisure time, at work, and sedentary behavior were collected, which facilitated the analysis of the ratio between these factors. Future studies could integrate multiple cycles, increasing the generalizability of the results and enabling a longitudinal analysis of behavioral patterns.

Another limitation relates to the use of the MVPA/SB ratio. Although this ratio offers an innovative approach to assessing the relationship between physical activity and sedentary behavior, it simplifies the complex nature of daily movement patterns. Not all sedentary behaviors carry the same health risks - for example, sitting while working at a desk may have different health implications than sitting during a social engagement [44]. Thus, by using a simplified ratio, we may miss important nuances in how different types of sedentary behavior impact health outcomes [59].

Conclusion

This study highlights the complex relationship between movement behaviors and sleep duration, emphasizing the importance of the context in which PA occurs. The findings suggest that while leisure-time MVPA is associated with longer sleep duration, occupational MVPA may have the opposite effect, potentially due to the physical and psychological demands of the workplace. These results underscore the need for public health interventions that encourage PA in leisure time while addressing the challenges posed by work-related physical demands, particularly in socioeconomically disadvantaged populations. Further research should aim to explore the mechanisms underlying these associations and develop targeted strategies to improve sleep health through balanced movement behaviors across different life contexts.

Declaration section

Ethical questions

All procedures were carried out according to the guidelines and standards for research involving human beings of the Declaration of Helsinki and were approved by the Research Ethics of the National Center for Health Statistics (NCHS) (reference number #2018-01), and each participant provided written informed consent. After anonymization, NHANES data is publicly available. Therefore, as NHANES data is publicly accessible, this study did not require additional ethical approval. Full information on NHANES study designs and data is available at www.cdc.gov/nchs/nhanes/.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44167-024-00067-3.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

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Author contributions

LTP, LAN, and LAAMJ supported or carried out the data collection. LTP, and LAN carried out the statistical analyses with the support of LAAMJ. LTP, and LAN drafted the first version of the manuscript. LTP, LAN, and LAAMJ carried out a substantive revision of the work. LAAMJ supervised the work. All the authors approved the submitted version.

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Data availability

The data used in this study were taken from the National Health and Nutrition Examination Survey database. The public data of NHANES are available at https://wwwn.cdc.gov/nchs/nhanes/.

Declarations

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Conflict of interest

We declare no competing interests.

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