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Impact of seasons and temperatures on the sleep-wake cycle in a French elderly rural population

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ABSTRACT

Sleep is known to be affected by season changes in a temperate climate. Temperature changes are known to affect sleep directly, but in this context, season-related changes in the circadian rhythm may play an important role as well. The objectives of this study were to verify the effect of season and temperature on sleep parameters of elderly French subjects and to focus on the sleep-wake cycle. Sleep parameters and sleep-wake cycle parameters were analyzed through actigraphy while seasonality and temperature were acquired from recording dates and weather records from online scientific archives. ANOVAs were carried out to investigate the effect of seasons on actigraphic parameters and to calculate regression models for temperature.

A sample of 157 subjects (49.7 % women) participated in the study with a mean age of 76.9 ± 4.5 years. Inter-daily stability of the sleep-wake cycle was higher in autumn and winter with a higher mean activity during those months. Time in bed was significantly longer in autumn and winter while there was a similar trend for total sleep time. Those variables changing with the seasons were negatively linked to ambient temperature.

Not only sleep but also the sleep-wake cycle is impacted by seasonal changes in elderly French subjects. Seasons should be taken into consideration when planning sleep-wake cycle recordings in temperate climates, in particular for longitudinal protocols. Clinical interventions should take season-related sleep-wake cycle problems into account, particularly in the elderly, who suffer more often from sleep disorders than other age groups. Since elderly also suffer more from climate change effects, this study further adds to the demand for clinical monitoring and housing adaptations for the elderly in the future.

1. Introduction

Circadian rhythms are an essential part of human life as they are a major synchronizer of physiology and behavior to the 24 h periodicity of the Earth's rotation [1]. This synchronicity improves the survival capacities of one's organism to the environment [2] but different situations can cause dysfunctions in the circadian rhythms such as shift work [3], diseases [4] and aging [5]. These dysfunctions could result in phase shifts or reduced amplitudes in circadian rhythms and represent warning signs of neurodegenerative diseases as they can appear before the onset of clinical and/or psychological symptoms in older people [6]. It is therefore important to have a basic understanding of their normal fluctuation inside their homeostatic range. In this study, we focus on one circadian rhythm that is easily observable, the sleep-wake cycle. A characteristic of this cycle is its bidirectional relationship with aging, i.e. aging impacts the sleep-wake cycle negatively, while a degraded sleep-wake cycle can accelerate aging [7,8]. Humans and other mammals regulate their sleep-wake cycle through both endogenous mechanisms, governed by the suprachiasmatic nucleus [9] and external cues known as zeitgebers. A zeitgeber is an external stimulus, such as light or a regularly recurring environmental factor, that helps synchronize an organism's biological clock. These rhythmic cues, including changes in light exposure [10], temperature, social interactions, physical environment [11,12] or feeding habits [13], play a key role in resetting the internal body clock and aligning it with the external environment. Artificial changes in those zeitgebers, such as shift work, have a negative

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impact on the sleep-wake cycle. Naturally occurring changes in those zeitgebers have been less studied and when reported, only mean sleep parameters were considered, while the 24 h cycle in which it exists was often ignored [14–17]. In this work we have studied the effect of seasons on the sleep-wake cycle (as a circadian rhythm encompassing sleep and diurnal activity), in a temperate region where four seasons alternate with different characteristics such as temperatures, light exposure, physical and social activities.

The seasonal effect on sleep (as an isolated phenomenon) has been studied in different populations. Data from pre-industrial societies in Africa and South America [17] as well as results from Japanese [14,15] and German [16] studies show that human sleep is longer in winter by an average of 1 h when compared to summer. The difference of total sleep time (TST) was significant in the pre-industrial societies and the older Japanese while it was a trend in the young Japanese and the German patients. This could be due to the difference in measurement devices, actigraphy versus polysomnography, or it could be due to a difference of sensibility to the seasonal zeitgeber. In both the pre-industrial societies and the Japanese elderly, a link between temperature and sleep was found. Yetish et al. found that sleep occurred during the period of decreasing ambient temperature, regardless of season, and that wake onset occurred at the lowest temperature of the 24 h cycle, not at the start of the light period [17]. Okamoto-Mizuno et al. showed that disturbed sleep in summer was related with significantly decreased proximal skin temperature, and decreased distal and mean skin temperature in the later portions of the sleep period [15]. Ambient temperature thus appears to play an important role in the timing of wake onset, while individual body temperature is a determining factor for the occurrence of sleep disruption [18].

Despite these results, few studies focus on the seasonal effect on the sleep-wake cycle as a whole. One study from Kume et al. used actigraphy to study the effect of seasons on 37 Japanese and 44 Thai older people [19]. They found the seasonal effect on TST in both populations with a shorter TST in summer but only found an effect of seasons on the sleep-wake cycle in Japanese older people and not in Thai older people. An explanation for these findings could be that Japan is under a temperate climate (four seasons with temperature changes) while Thailand is under a tropical climate (three seasons with no significant temperature changes). After a multiple comparison test, Kume et al. showed that there is more activity during the night in summer (with the least 5 h variable, i.e. L5) while intra-daily variability (IV) was higher in winter than in all other seasons. This contradicts other data showing that IV is negatively correlated to TST [20]. This discrepancy in their results was not discussed in Kume et al. paper. Due to this discrepancy and based on cultural differences in sleep-wake cycle characteristics between populations, it should be interesting to explore seasonal effects on sleep and sleep-wake cycle in a European population while considering the effect of temperature.

The objective of this study was thus to investigate the seasonal effect on the sleep-wake cycle in older French people living in a rural part of France (Gironde, with a temperate climate), as they could be more sensitive to season changes. Our first research objective focused on whether sleep duration is longer in winter, as reported in the literature, and whether the sleep-wake cycle is more stable, particularly with higher inter-daily stability, during this season. Our second research objective focused on whether ambient temperature impacts the sleep-wake cycle. To the best of our knowledge, this is the first study on the relation between seasons, temperature and the sleep-wake cycle in Europe on a large sample of participants.

2. Methods

2.1. Population

The Aging Multidisciplinary Investigation (AMI) cohort is an epidemiological prospective study started in 2007 in Bordeaux, France. It regroups participants older than 65 years old, living in the Gironde region, who have been working for more than 20 years in agriculture. The study procedure was approved by a regional human research review board (University Hospital of Bordeaux, Committee for the Protection of Persons number 2011-A01393-38) and all participants provided written informed consent. All participants were right-handed and had no neurological or psychiatric disorders based on a clinical interview.

AMImage is an ancillary research project of AMI, in which brain imaging and actigraphy measures were proposed to AMI participants between 2012 and 2014, in addition to biennial follow-ups provided by epidemiologists at the Bordeaux Population Health center. A total of 160 persons accepted to participate in this study. Three participants were diagnosed with Alzheimer's disease. Individuals who develop Alzheimer's disease experience sleep-wake cycle dysregulation that surpasses the typical age-related changes observed in healthy individuals. To maintain the focus on age-related healthy sleep patterns, these patients were excluded leaving 157 persons for our study.

2.2. Actigraphy assessment

Two different type of wrist-worn actigraphs were used to measure sleep and sleep-wake cycle, The ActiWatch 7 and the MotionWatch 8 (Cambridge Neurotechnology, Cambridge, UK), both validated against polysomnography [21,22]. To use both actigraph devices in the same study, the MotionWatch8 actigraph was set up applying MotionWatch Mode 1 that replicates the set-up of the ActiWatch 7. The devices were placed on the nondominant wrist and were worn continuously for a week in the home environment. MotionWare software (version 1.2.26; Cambridge Neurotechnology, Cambridge, UK) and manufacturer algorithms were employed to identify and analyze sleep, based on 1-min epochs with a sensitivity threshold of 20 counts. The determination of sleep versus wakefulness during each epoch was made by comparing activity counts of the epoch in question to a threshold value, which was validated using surrounding activity counts [23]. A sleep diary informing about bedtime and rise time was completed by each participant during the protocol and was used to improve data scoring through correction of the sleep period detection by the algorithm.

Sleep parameters used in the analyses are the following: Time In Bed (TIB); TST; Wake After Sleep Onset (WASO); Sleep Efficiency (SE), Sleep Fragmentation (SF) and Sleep Onset Latency (SOL). Those parameters have been defined previously [24].

For sleep-wake cycle, Non-Parametric Circadian Rhythm Analysis (NPCRA) [25] was used and five parameters were computed: L5 (the average activity level for the sequence of the least five active hours); Most 10 (M10, the average activity level for the sequence of the ten most active hours); Relative Amplitude (RA, $\frac{M10-L5}{M10+L5}$); Inter-daily Stability (IS, the degree of regularity in the activity-rest pattern or the inverse of intra-individual variability in the activity-rest pattern) and Intra-daily Variability (IV, the degree of fragmentation of activity-rest periods).

2.3. Seasonality

Gironde is part of the Nouvelle-Aquitaine region in *Southwestern France* (latitude 44° 50′ 58.794″ N and longitude 0° 27’ 0.852” W). The climate is classified as warm temperate and humid [26]. There are four seasons during the year: Autumn from September to November; Winter from December to February; Spring from March to May and summer from June to August.

Mean temperatures per months in Gironde were acquired from meteorologic archives (https://www.historique-meteo.net/). For each actigraphic recording, the corresponding month temperature was entered as a variable. In this French region, the mean external temperature in Autumn was 11.0 °C; 9.2 °C for Winter; 14.3 °C for Spring and 21.8 °C for Summer.

2.4. Other assessments

Body mass index (BMI) was recorded, and educational level was categorized in three levels (primary school or less; high school and university). The Mini Mental State Examination (MMSE) was used to evaluate global cognitive status. Sleep apnea diagnosis was self-reported. Consumption of psycholeptic/neuroleptic drugs was assessed (anxiolytics, hypnotics, sedatives, and antipsychotics).

2.5. Statistical analyses

All statistical analyses were performed using R Studio v4.3.1. Normal distribution of variables was tested with the Shapiro normality test (shapiro.test function) and normalized, if necessary ("Normalize" function from the "QuantPsyc" package), before being described with means (m) and standard deviations (sd).

2.5.1. Age and sex effects on actigraphic parameters

Pearson correlations were used to study the possible effect of age on actigraphic parameters. Student's t tests were used to compare actigraphic parameters between sex groups. Statistical significance was set at $p < 0.05$ with False Discovery Rate (FDR) for multiple comparisons correction.

2.5.2. Season effects on actigraphic parameters

First, season's groups were compared in terms of sex with Chi 2 test ("chisq.test" function) and age, BMI and MMSE with Kruskal test ("kruskal_test" function from the "rstatix" package").

Multiple factors ANOVAs were used to determine the effect of the four seasons on sleep and sleep-wake cycle parameters while taking into consideration sex and age when appropriate ("ezANOVA" function from the "ez" package). Application conditions were verified, and outliers were removed for each ANOVA with the "identify_outliers" function ("rstatix" package) which use a boxplot method to identify outlier outside of Q3 + 1.5xIQR and Q1 – 1.5xIQR (Q: quartile; IQR: interquartile range). If the homogeneity of variance was not satisfied, a non-parametric test was used ("kruskal_test" function from the "rstatix" package"). In case of an interaction effect between seasons and sex, a one-way ANOVA was used to analyze the effect of seasons in each sex groups. In case of a significant effect, post-hoc tests were realized with "TukeyHSD" function ("stats" package) with an adjustment for multiple comparisons. Statistical significance was set at $p < 0.05$.

2.5.3. Temperature effects on actigraphic parameters

In case of a seasonality effect, regression models (function "lm" from the "stats" package) were performed to test the possibility of a temperature effect with the appropriate covariates. Statistical significance was set at $p < 0.05$.

All analyses were also conducted in a sample of participants without any reported sleep problem ($n = 125$). Three participants reported sleep apnea, 3 reported restless-legs syndrome and 26 used medications with an impact on sleep.

3. Results

3.1. Participant characteristics

Demographic parameters for the 157 participants and the subsample without reported sleep problems ($n = 125$) are presented in Table 1. The distribution in education levels is as follows: 28.7 % primary school or less; 33.7 % secondary school; 37.6 % high school or more.

3.2. Age and sex effects on actigraphic parameters

All actigraphic parameters are presented in Tables 2 and 3 by seasons. There was no significant link between age and sleep parameters, only a relation that did not hold multiple comparisons correction with TST ($R = 0.17$; $p = 0.038$; p FDR $= 0.131$). But there was an age effect on M10 ($R = -0.31$; $p < 0.001$; p FDR $= 0.002$) and on IV ($R = 0.24$; $p = 0.003$; p FDR $= 0.024$) as well as a relation that did not hold FDR correction on RA ($R = -0.17$; $p = 0.028$; p FDR $= 0.121$). In the subsample without sleep problems, age effects were only trends.

Table 1
Participant characteristics.

Variables	Whole sample (N = 157)	Subsample (N = 125)
	Mean ± SD	Mean ± SD
Age, years	76.9 ± 4.51	76.5 ± 4.3
Women, %	49.7	45.6
Recording length, days	7.6 ± 0.8	7.6 ± 0.8
BMI[a]	26.2 ± 3.5	26.2 ± 3.3
MMSE[b]	26.8 ± 2.6	26.9 ± 2.2

Abbreviations: BMI, Body Mass Index; MMSE, Mini Mental State Examination.

[a] Missing data for 18 participants.

[b] Missing data for 14 participants.

Women had a less fragmented sleep than men (FI = 28 ± 11 vs 33 ± 11; $p = 0.005$; p FDR $= 0.030$) and had a higher SE (84 ± 7 vs 82 ± 7; $p = 0.034$; p FDR $= 0.101$) that did not hold FDR correction. A significant difference between sex for IS was observed with a higher IS in women (0.709 ± 0.112 vs 0.622 ± 0.109; $p < 0.001$; p FDR <0.001). Those sex differences were also observed in the subsample without reported sleep problems.

3.3. Seasonality effect

3.3.1. Season's groups

There was no difference between the groups in term of age, sex, BMI and MMSE ($p > 0.05$) in the whole sample or in the subsample without sleep problems.

3.3.2. Sleep parameters

We found a statistically-significant difference in TIB by seasons (F (3,149) = 5.06; $p = 0.002$) (Fig. 1). A Tukey post-hoc test revealed that Summer resulted in a lower TIB on average than Autumn (−64.3 min; p adj = 0.005), and Winter (−46.2 min; p adj = 0.044). Spring also resulted in a lower TIB on average than Autumn (−34.1 min; p adj = 0.025) (Fig. 1). In the subsample without sleep problems, the same results were found (F (3,118) = 6.03; $p < 0.001$) with a lower TIB on average in Summer compare to Autumn (−64 min; p adj = 0.009) and Winter (−51 min; p adj = 0.022). Spring resulted in a lower TIB on average than Autumn (−41 min; p adj = 0.018) and Winter (−27.9 min; p adj = 0.035).

We detected a trend between seasons and TST (F (3,155) = 6.81; $p = 0.078$) that did not exist in the subsample without sleep problems.

There was no result regarding WASO, SE, FI and SOL in the whole sample and the subsample without sleep problems.

3.3.3. Sleep-wake cycle parameters

We found a significant difference in M10 (counts) by seasons (F (3,149) = 9.05; $p < 0.001$) while controlled by age (Fig. 2). A Tukey post-hoc test revealed that Summer resulted in a lower M10 on average than Winter (-4633; p adj = 0.042). In the subsample without sleep problems, seasons effect were still significant on M10 (F (3,117) = 2.79; $p = 0.044$) controlled by age with a lower M10 in Summer compared to Winter (-4941; p adj = 0.028).

There was also a statistically-significant difference in IS for both seasons (F (3,146) = 4.07; $p = 0.008$) and sex (F (1,146) = 6.22; $p = 0.014$) with no interaction effect (F (3,146) = 2.35; $p = 0.075$) (Fig. 3). Because there is no significant interaction effect between seasons and sex, we did not stratify the analyses. A Tukey post-hoc test revealed that Spring resulted in a lower IS on average than Autumn (-0.081; p adj =

Table 2
Sleep parameters by seasons.

Variable	Autumn (n = 25)		Winter (n = 68)		Spring (n = 53)		Summer (n = 11)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TIB, hours	9h04$^{*\#2}$	0h46	8h46$^{\#}$	0h49	8h30$^{\#2}$	0h54	8h00$^{*\#}$	0h28
TST, hours	7h30	0h43	7h14	0h53	7h06	1h04	6h47	0h21
WASO, hours	1h15	0h23	1h05	0h31	1h03	0h26	0h54	0h20
SE, %	82.1	6.7	83.2	6.4	83.0	7.6	83.3	4.4
FI, %	32.5	11.2	30.0	11.8	31.1	10.9	30.1	7.5
SOL, minutes	12	12	12	12	11	13	16	14

Abbreviations: TIB, Time In Bed; TST, Total Sleep Time; WASO, Wake After Sleep Onset; SE, Sleep Efficiency; FI, Fragmentation Index; SOL, Sleep Onset Latency.
Tukey post hoc test: $p < 0.01$ *; $p < 0.05$ $^{\#}$ for Summer; $p < 0.05$ $^{\#2}$ for Spring.

Table 3
Sleep-wake cycle parameters by seasons.

Variable	Autumn (n = 25)		Winter (n = 68)		Spring (n = 53)		Summer (n = 11)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Least 5	609	215	640	444	611	369	489	180
Most 10	14,931	4834	14,923$^{\#}$	4623	14,105	5558	10,462$^{\#}$	2095
Relative Amplitude	0.904	0.060	0.912	0.036	0.915	0.048	0.926	0.036
Inter-daily Stability	0.711*	0.089	0.680$^{\#}$	0.117	0.624$^{*\#}$	0.126	0.662	0.093
Intra-daily Variability	0.807	0.182	0.779	0.179	0.848	0.253	0.826	0.270

Tukey post hoc test: $p < 0.01$ *; $p < 0.05$ $^{\#}$

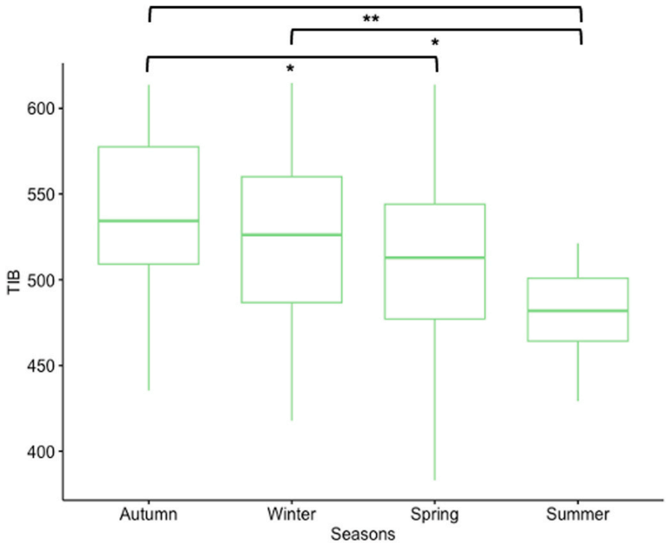

Fig. 1. Time in bed (in minutes) changed depending on seasons. Abbreviation: TIB, man Time In Bed.

0.010), and Winter (-0.053; p adj = 0.028). In the subsample without sleep problems, the same results were found for seasons (F (3,117) = 4.14; p = 0.008) and sex (F (1,117) = 5.51; p = 0.012) without interaction effect (F (3,117) = 1.99; p = 0.119). Spring resulted in a lower IS than Autumn (-0.097; p adj = 0.008).

There was no result regarding L5, RA and IV in the whole sample and the subsample without sleep problems.

3.4. *Temperature effects on actigraphic parameters*

3.4.1. *Linear models were realized for TIB, IS and M10*

There is a slight statistically-significant relation between TIB and temperature, with a decrease in TIB of 2.6 min for every 1 °C increase (R^2 adj = 0.03; F (1,151) = 5.7; coef. = −2.6; p = 0.019). The same result was found in the sample without sleep problems (R^2 adj = 0.07; F (1,120) = 10.3; coef. = −3.7; p = 0.002).

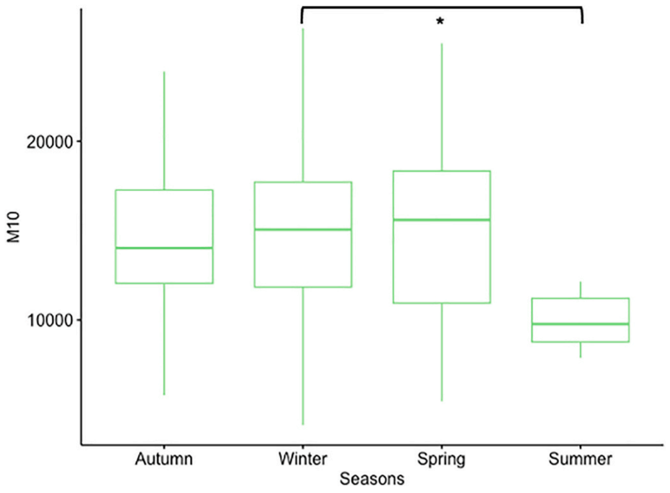

Fig. 2. M10 (in quantity of activity) changed depending on seasons, corrected by age. Abbreviation: M10, Most 10.

There was no link between M10 and temperature in the whole sample but, in the sample without sleep problems, a statistically-significant relation between M10 and temperature was found in a model with age (R^2 adj = 0.07; F (2,118) = 5.2; p = 0.007). M10 was significantly predicted by temperature (coef. = −264, p = 0.030) and age (coef. = −226, p = 0.024) in this sub-sample.

There was a statistically significant relation between IS and temperature in a model with sex (R^2 adj = 0.16; F (2,151) = 15.4; p < 0.001). IS decrease of 0.005 point for every 1 °C increase in temperature (coef. = −0.005, p = 0.015) and IS higher in women (coef. = 0.083, p < 0.001). The same relation was found in the subsample without sleep problems (R^2 adj = 0.14; F (2,122) = 11.0; p < 0.001) with an effect of temperature (coef. = −0.005; p = 0.042) and sex (coef. = 0.085; p < 0.001).

4. Discussion

The aim of this study was to analyze the possible impact of seasons

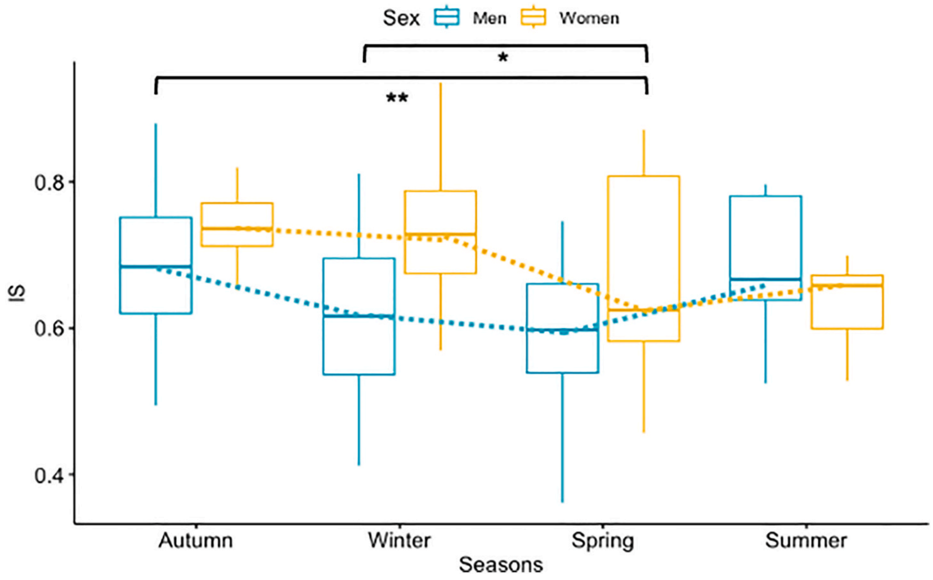

Fig. 3. IS changed depending on seasons and sex. Abbreviation: IS, Inter-daily Stability.

on the sleep-wake cycle in a large rural cohort of elderly French people. Interestingly, Inter-daily Stability (IS) was higher in autumn and winter compared to spring, indicating less day-to-day variability in the sleep-wake cycle of this elderly population. The average activity level for the sequence of the ten most active hours (M10) was higher in winter compared to summer. Time In Bed (TIB) was objectively longer in autumn and winter. Also, a negative correlation was found between external temperatures and IS, M10 and TIB; with lower temperatures, IS, TIB M10 increase. In these cross-sectional analyses, no age effect on isolated sleep parameters was observed but one was found on the sleep-wake cycle as a whole. With advancing age, there is less activity during the day (i.e. M10) and more fragmentation of activity-rest periods (i.e. IV).

In regards to our first hypothesis, while we found a seasonal difference in TIB, there was only a trend for TST contrarily to what can be found in the literature [15,17]. In their study, Yetish et al. do not report TIB while in Okamoto-Mizuno and Tsuzuki's study, no significant difference in TIB by seasons despite a change in SE was reported. Our study population may have different TIB in summer because of a difference in activities. Indeed, it is a population of retired farmers who use to have an active life, with physical activities that remain through gardening and sometimes helping in the family farm. They might also not stay in bed because of the rising temperature since their TIB was negatively correlated to the external temperature. Considering that high temperature through the night is deleterious for sleep [27], they might not be staying in bed because they are uncomfortable.

For our second hypothesis, we found a seasonal difference with a stronger cycle in autumn and winter, i.e. our participants were more active (higher M10) and had a more stable cycle (higher IS). There was also an effect of sex on IS with women having a more stable cycle than men. This difference seems to disappear in summer, but this could be due to the low number of participants of whom we could analyze data during this season. Conversely, Kume et al. found a higher IV in winter and a higher L5 in summer [19]. This could be due to some differences in study setup: Kume et al. used repeated measures on a small sample, they did not specify if their Japanese sample lived in the city or in a rural area. In addition, cultural and lifestyle differences cannot be excluded as contributing to the different results [28]. In our population, we also found that the sleep-wake cycle parameters which changed with the seasons are correlated with temperature. The higher the temperature, the less stable the sleep-wake cycle was, along with a lower activity.

Limitations should be considered for our study. First, groups sizes are different due to the availability of the subjects who were more likely to participate in the research project during winter and spring. But after verification of confounding variables between the seasonal groups, no age, sex and BMI differences were observed. The small number of participants in summer made the analysis on IS less powerful. Second, light exposure (despite the light sensor in the actimeters) could not be investigated. Data on light exposure was frequently lost because participants often covered the actimeter with their sleeves, which rendered the measure unfit to study, particularly during the cold months. Third, there was no information on time spent outside or on household technology (air conditioning, heating) to control ambient temperature. Finally, this study was done on a particular population and should be replicated in an urban group.

In conclusion, we found a significant effect of seasons on the sleep-wake cycle in an elderly French rural cohort. This population is characterized by a stable day-and night rhythm and sleep opportunity: they are no longer impacted by phase-advanced shifts created by their work schedules and thus have lower variability in sleep and wake times between weekdays and weekend days. They also live in a rural part of France, thereby less exposed to noise and light pollution.

The results also show the importance of the time of recording for actigraphy. That is to say, the results implicate that it is advisable to record all participants in the same season for cross-sectional studies and to record the same participants in the same season for longitudinal studies if possible. If not, a verification should be made to ensure that season does not bias the results. Moreover, the observed effect of higher temperature on the sleep-wake cycle adds to the growing literature of temperature effects on sleep. There is an increase in global temperature due to climate change, which affects not just overall temperatures (warmer winters, hotter summers) but also leads to more extreme weather events (more frequent heatwaves, storms, rainy periods). It is more and more important to know its consequences on our health, on the health of at-risk populations such as the elderly. This age group is known to be particularly affected by extreme weather events [29]. Further, recent studies show that climate change affects mostly nighttime temperatures more than daytime temperatures [30], making monitoring and optimizing the health and housing of the elderly a high priority for general practitioners and policy makers [31,32]. Besides, while practical recommendations exist to manage sleep problems during heatwaves [33], the equivalent for sleep-wake cycle issues remains yet to be investigated.

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The data underlying this article cannot be shared publicly to respect the privacy of individuals that participated in the study. The data will be shared on reasonable request to the corresponding author.

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CRediT authorship contribution statement

Aurore Jouvencel: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Ellemarije Altena:** Writing – review & editing, Supervision. **Karine Pérès:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization. **Jean-François Dartigues:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization. **Héléne Amieva:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization. **Willy Mayo:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Gwenaëlle Catheline:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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