2019

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Original Publication Citation

Lubas, M. M., Maduro, R. S., & Szklo-Coxe, M. (2019). An exploratory study examining the associations between sunlight exposure, sleep behaviours and sleep outcomes during an Arctic summer. *International Journal of Circumpolar Health, 78*(1), 1-12 (1574698).
doi:10.1080/22423982.2019.1574698

INTERNATIONAL JOURNAL OF CIRCUMPOLAR HEALTH
2019, VOL. 78, 1574698
https://doi.org/10.1080/22423982.2019.1574698

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An exploratory study examining the associations between sunlight exposure, sleep behaviours and sleep outcomes during an Arctic summer

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ABSTRACT

Few evidence-based recommendations exist for maintaining healthy sleep during Arctic summers. Our study aimed to examine associations between sleep hygiene, sunlight exposure and sleep outcomes in workers living in and/or near the Arctic Circle during a 24-h light period. A survey was administered July 2017 to 19 workers at 3 Arctic base camps in Northeastern Alaska. Participants with poorer sleep hygiene reported increased sleepiness ($r=.62$, $p=0.01$); this correlation remained moderately strong, albeit not statistically significant (NS), after controlling for shift work ($r=.46$, $p=0.06$). No other statistically significant correlations between sleep hygiene and sleep outcomes were found. Weekly daytime (<8pm) and evening (>8pm) sunlight exposures, estimated from daily self-reported sunlight exposures for a typical workday and day off, were dichotomised, based on means, into: longer (>45 h/week) versus shorter (<45 h/week) daytime exposures, and longer (>16 h/week) versus shorter (<16 h/week) evening exposures. Participants reporting longer, versus shorter, weekly daytime sunlight exposure had statistically significantly (Mann-Whitney $U=18.00$, $Z=-1.98$, $p\leq0.05$) decreased median sleep duration (6 h, 18 min versus 8 h, respectively) during the past month. Correlations of $r\geq.3$ for longer, vis-à-vis shorter, daylight sunlight exposure suggest it could be related to poorer sleep outcomes, such as insufficient sleep and sleep quality, yet, as these correlations were NS, future work is needed to determine this. Weak or no correlations (and NS differences) were found for longer, versus shorter, weekly evening sunlight exposure and sleep outcomes. Findings support previous research suggesting self-regulation behaviours alone are not protective against poor sleep in Arctic environments. Sleep outcomes did not differ statistically significantly by evening sunlight exposure length. Longer weekly daytime sunlight exposure, versus shorter, was significantly associated with decreased sleep duration. Results from this exploratory study should be confirmed in studies using larger sample sizes.

ARTICLE HISTORY
Received 9 November 2018
Revised 10 January 2019
Accepted 21 January 2019

KEYWORDS
Sunlight exposure; sleep hygiene behaviours; sleep quality; sleep duration; Arctic; subarctic; Alaska

Introduction

Sleep is a complex physiological process regulated through the interaction of two systems, circadian rhythms and sleep-wake homeostasis [1,2]. Sleep cycles are influenced by both endogenous and exogenous factors [3]. Exogenous factors refer to time cues that can influence sleep, such as work and leisure schedules, food intake, stress, ambient temperature and light. Light is a principal factor in the circadian rhythms of all species and is a strong determinant in regulating periods of sleep and wakefulness [4,5]. Previous studies have shown that light exposure in the late afternoon can delay the internal circadian rhythm of an organism (both human and animal), and that light in the morning can advance circadian rhythms [6,7]. The presence of light is a significant regulatory agent for the human circadian system, and living in environments that experience large seasonal variations in photoperiods (day length) poses risks to the circadian system. Thus, further studies are needed to examine the effects of light on humans in environments with large seasonal variations in day length.

Sleep research in Arctic and Antarctic settings have often focused on winter months, examining sleep during periods of increased darkness. A review [8] of research in polar regions supports that circadian system desynchrony is common in Arctic and Antarctic environments during periods of decreased natural light and is related to an increase in sleep disturbances. During the winter months, workers in the Arctic (Sweden) reporting decreased natural light exposure reported an increased prevalence of insufficient sleep compared to workers in an equatorial setting (Brazil) with increased natural light exposure [9]. A sample of construction expeditioners in Antarctica experienced decreased sleep efficiency and decreased slow wave sleep in winter months relative to their own baseline sleep measurements in India [10]. A subarctic sample of

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Norwegian university students reported increased sleep onset latency (SOL) and poorer sleep efficiency compared to university students from Ghana during the winter [11]. When comparing sleep outcomes across seasons within Antarctic, Arctic and subarctic environments, increased insomnia symptoms [11–14], decreased sleep efficiency [11,13], increased SOL [11,14], delayed sleep timing [11,13] and decreased slow wave sleep [10] were found to be more prominent in winter than summer months. Increased sleep disturbances during winter months in polar regions have been documented when comparing these extreme photoperiod environments to non-polar environments with small seasonal variations (e.g. equatorial settings) [9–11], and when comparing seasonal variations within polar (Antarctic, Arctic) and subarctic environments [10–14]. Sleep disturbances have thus been found to be increased during winter months in environments with decreased day length.

Less is known about sleep during the summer months in polar regions as, to date, fewer studies have been conducted, as indicated in a 2018 review [15]. However, similar sleep disturbances, albeit sometimes less pronounced, remain present in polar residents during periods of increased natural light as during periods of darkness [10,15–17]. During the summer months in Antarctica, a sample of expeditioners were found to experience an increase in SOL and a decrease in total sleep time compared to their baseline sleep measurements collected outside of the Antarctic environment [10]. Pattyn and colleagues [18] found that living in the Antarctic summer was associated with poor sleep quality, increased sleepiness and difficulty maintaining sleep; this study compared the sleep of Antarctic construction expeditioners to an age, gender and body mass index matched control group of “good sleepers” in Belgium. Brychta et al. [16] examined seasonal variation in sleep in a subarctic Icelandic sample of older adults. While SOL was slightly decreased during summer (39.5 min) versus winter months (45.2 min), this difference was not statistically significant, indicating increased SOL even during summer months [16]. Some sleep disturbances may also worsen during the summer months in polar regions. Paul et al. [17] found that their Arctic sample of Canadian Forces personnel experienced statistically significantly decreased sleep duration (at 50 min) during summer versus winter months. Thus, in Arctic, Antarctic and subarctic environments during seasonal periods of increased natural sunlight, increased day length has been associated with an increased SOL [11,16], decreased sleep duration [17], poor sleep quality [18] and increased insomnia symptomatology [14].

Poor sleep has thus been documented in environments with extreme seasonal variations in sunlight [8,11,13–18]. However, more information is needed on behavioural factors that may help improve sleep in these environments. While it is understood that circadian rhythms are disrupted during large seasonal shifts in light, less is known about the role dysfunctional sleep behaviours may play in contributing to poor sleep in these environments, especially during periods of increased natural light. Whether the amounts of daytime and/or evening sunlight exposure are associated with sleep outcomes is also unknown. Ultimately, recommendations for residents of polar regions surrounding sunlight exposure and sleep hygiene behaviours have not been thoroughly studied.

The purpose of our study was thus to further examine variables that may serve as protective factors for healthy sleep in Arctic environments during periods of increased light. In this exploratory study, we examined the associations between sleep hygiene behaviours, self-reported sunlight exposure and sleep outcomes in a sample of workers living in and/or near the Arctic Circle during a summer period of 24-h light. The study consisted of two primary aims. Aim 1 was to examine the associations of sleep hygiene behaviours with sleep outcomes. Aim 2 was to examine the associations between the number of hours of daytime and evening sunlight exposures and a range of sleep outcomes.

Materials and methods

Study participants, setting and study design

Study participants were comprised of individuals who worked at three Arctic base camps in northeastern Alaska, located in or near (approximately 60 miles south of) the Arctic Circle. These base camps serve as hospitality centres offering food, lodging and gasoline, throughout a remote area of Alaska. The camps operated 7 days a week, two on a 24-h basis, one during the hours of 4am to 11pm. Workers at the study setting were employed in various roles, such as food service workers, housekeeping/maintenance staff and in camp management. Inclusion criteria were as follows: (i) age 18 years or older; (ii) current employee at the Arctic base camp; and (iii) having arrived at the Arctic base camp no later than 15 June 2017. The convenience sample thus consisted of approximately 44 workers who were eligible to complete the survey, of which 19 consented and agreed to participate in the study. The one-time survey was self-administered by the workers. Surveys were available in a common area of each camp in mid-July 2017 and, upon completion, were returned via mail to the research team by mid-August 2017. The study was approved by the institutional review board prior to survey administration and data collection.

Variables

Dependent (outcome) variables included self-reported measures of sleep. Sleep measures were assessed on the survey by asking participants to self-report their sleep "during the past month". The Pittsburgh Sleep Quality Index (PSQI) assessed overall sleep quality. The PSQI is a reliable and valid 19-question measure that assesses sleep quality and sleep patterns [19]. Overall sleep quality scores on the PSQI range from 0 to 21 and are based on the scoring of seven components: subjective sleep quality, sleep onset latency (SOL), sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication and daytime dysfunction. A score >5 identifies the clinical cut-off for poor sleepers. In addition to the overall sleep quality score, we also examined three components of the PSQI as individual outcomes: SOL, sleep duration and sleep efficiency. SOL was assessed via a PSQI question, "during the past month, how long (in minutes) has it usually taken you to fall asleep each night?" Sleep duration was assessed via a PSQI question, "during the past month, how many hours of actual sleep did you get at night?" Sleep efficiency is the ratio of total sleep time compared to the total time spent in bed and was calculated according to the PSQI instructions.

Insomnia symptoms were assessed through the Insomnia Severity Index (ISI) [20], a 7-question measure with demonstrated reliability and validity in assessing insomnia symptom severity [20,21]. ISI scores range from 0 to 28. Scores <8 indicate no clinically significant insomnia, scores between 8 and 14 are suggestive of subthreshold insomnia and scores ≥15 indicate clinical insomnia with higher scores suggesting more severe insomnia.

Single question items assessed sleepiness and insufficient sleep. Sleepiness was measured by asking participants to report their sleepiness on a typical day (daytime sleepiness) on a scale of 1–10 [22]; insufficient sleep, by asking participants to report the number of days during the past month that they felt they did not get enough rest or sleep.

Independent (predictor) variables included self-reported sleep hygiene behaviours and sunlight exposure. An adapted version of the Sleep Hygiene Index (SHI) [23] assessed sleep behaviours. The SHI is a 13-item measure that assesses sleep hygiene behaviours. One question about bedroom environment ("I sleep in an uncomfortable bedroom") was excluded from the SHI as study participants did not have control over selecting their bedroom sleeping arrangements. The SHI does not have a cut-off score classifying poor sleep hygiene; however, higher scores on the scale indicate more maladaptive sleep habits [23]. Based on the 12 items included, a score ranging from 0 to 48 was possible.

Sunlight exposure duration was assessed continuously, as well as categorically, and for different time frames (daytime and evening). Daytime sunlight was defined as exposure prior to 8pm, and evening sunlight was defined as exposure after 8pm. The cut-off of evening light (after 8pm) was defined according to the findings of Paul and colleagues [24], suggesting that limiting light exposure after 8pm may improve sleep during the Arctic summers. The time period identified as the "biological night" can vary among individuals depending on their chronotype [25]; therefore, previous Arctic research was used to inform the operationalisation of the sunlight exposure variables. Specific explanations for the sunlight exposure variables follow below.

Daily duration of sunlight exposure variables (continuous): Participants were asked on the survey (open-ended question) to estimate the number of hours of daily daytime (prior to 8pm) and evening (after 8pm) sunlight exposures they obtained for both a typical workday and for a day off. These variables are referred to as daily daytime sunlight exposures and daily evening sunlight exposures.

Weekly variables (categorical): Weekly daytime sunlight exposure (<8pm) and evening sunlight exposure (>8pm) were derived from the daily sunlight (self-reported sunlight exposure for a typical workday (before and after 8pm) and day off (before and after 8pm)); they were then estimated for a 7-day week on the basis of five work days and two days off, a schedule maintained by most participants. These weekly estimates of daytime and evening sunlight exposure were subsequently dichotomised into longer and shorter sunlight exposures based on the sample means. This variable was dichotomised as longer (>45 h/week) versus shorter (<45 h/week) daytime sunlight exposures; and longer (>16 h/week) versus shorter (<16 h/week) evening sunlight exposures. The dichotomisation of light exposure into short and long durations using the relative mean of self-reported exposure is an approach that has been previously used to examine sunlight and sleep outcomes in Arctic research [9]. These weekly variables for sunlight exposure duration are referred to as weekly sunlight exposure daytime and evening.

Descriptive survey variables consisted of demographic, lifestyle, and sleep-related questions. Basic demographic information included residency status (seasonal employee or Arctic resident), gender, race, education level and age. Lifestyle variables potentially related to sleep were also included, such as alcohol intake (weekly), current tobacco use (regular use in the past month), caffeinated beverage intake (daily), exercise habits (daily) and shift work, defined as working rotating shifts. Background sleep-related questions included: history of a diagnosed sleep disorder (open ended question), the use of sleep medications over the past month (yes/no) and frequency of use, the use of alerting medications over the past month (yes/no) and frequency of use, and chronotype, a measure of morningness or eveningness that was assessed by the Circadian Energy Scale (CIRENS) [26]. The CIRENS scale is a two question measure that assesses energy levels in the morning and in the evening to help classify chronotype. It has concurrent validity with other measures of chronotype [26], including a widely used measure, the Horne and Ostberg Morningness-Eveningness Questionnaire [27].

Statistical analysis

Descriptive statistics for the sample's demographic, lifestyle, and sleep characteristics were summarised. Associations between sleep hygiene and sleep outcomes (aim 1) were examined through bivariate and partial correlations. Associations between self-reported sunlight exposure and sleep outcomes (aim 2) were examined through two approaches. First, the bivariate correlations of daily daytime and evening exposures for a typical workday and day off were examined with respect to sleep outcomes. Second, after deriving the weekly sunlight exposures from the daily measures, and dichotomising them, Mann-Whitney tests were used to compare differences between the medians of two independent groups of sleep outcomes with respect to longer versus shorter sunlight exposure durations for both weekly daytime and weekly evening sunlight. Tests were considered statistically significant when $p \leq 0.05$. Given the exploratory nature of the study, we also reported moderate correlations ($r \geq .3$), which were defined according to Cohen's effect size conventions [28]. The 95% confidence intervals were calculated for correlations using Fisher's Z transformation [29]. Data were analysed using SPSS version 24.

Preliminary analyses examined correlations between descriptive and independent variables (sleep hygiene behaviours, daily sunlight exposure), and between descriptive and dependent variables (sleep outcomes). Due to statistically significant correlations between shift work and SHI scores ($r=.77$, $p<.001$), and between shift work and sleepiness ($r=.47$, $p=.04$), a decision was made to compute partial correlations adjusting for shift work between SHI scores and sleep outcomes. Partial correlations were reported for sleep outcomes that were statistically significantly correlated with SHI scores.

Results

Descriptive analyses

The survey response rate was 43% (n=19). Participants included males (42%) and females (58%) and were predominately Caucasian (84%). The sample ranged in age from 22 to 69 years, with mean age 39 years. Of the sample, 63% reported working rotating shifts. Three respondents reported a history of diagnosed sleep apnoea (16%); no other sleep disorders were reported in the sample. Nearly half of the sample (47%) reported sleep medication use during the past month; examples included: melatonin (n=4), diphenhydramine (n=4), zolpidem (n=1), valerian root (n=1), lorazepam (n=1) and acetaminophen pm (n=1). Table 1 summarises the percentage and frequency of demographic and other descriptive variables.

Table 2 summarises the mean (SD) and median (range) values for sleep outcomes for the study sample, with four of the measures based on the PSQI measure. Approximately half of the sample (53%) scored above the clinical cut-off for the PSQI (>5), indicating poor sleep quality. Sleep duration averaged 7 h and 6 min, with a mean SOL of approximately 29 min for the past month. The sample mean for the ISI was 6.79. All participants scored below the clinical cut-off score for the ISI measure (<15), indicating an overall absence of clinically significant insomnia in the sample. The sample mean for subjective daytime sleepiness was a score of 3.5 out of 10, with a range of 1–7. Participants reported an average of 8 days out of the past month during which they experienced insufficient sleep; the sample range was 2–31 days.

Sleep hygiene behaviours and sleep outcomes (study aim 1)

The possible range of Sleep Hygiene Index (SHI) scores was 0–48, with higher scores indicating poorer sleep hygiene. Participants' SHI scores ranged from 7 to 31, with an average score of 17. Table 3 presents correlation coefficients between the SHI scores and sleep outcome measures. There was a statistically significant association between poorer sleep hygiene and increased daytime sleepiness ($r=.62$, $p=0.01$). This correlation remained moderately strong though no longer statistically significant after controlling for shift work ($r=.46$, $p=0.06$).

Sunlight exposure and sleep outcomes (study aim 2)

Table 4 presents the correlation coefficients between daily sunlight exposure duration (continuous) variables

Table 1. Demographic, lifestyle and sleep characteristics of the study sample (n=19).

Variable	Category	% (n)
Demographic		
Arctic Residency	Year-round Arctic Resident	47% (10)
	Seasonal Employee	53% (9)
Gender	Male	42% (8)
	Female	58% (11)
Race/Ethnicity	White	84% (16)
	Other[a]	16% (3)
Education Level	High School Diploma or GED	16% (3)
	Associate's or Technical Degree	11% (2)
	Bachelor's Degree	63% (12)
	Advanced Degree	11% (2)
Age (years)	18–24	16% (3)
	25–34	42% (8)
	35–59	26% (5)
	60 and older	16% (3)
Lifestyle		
Caffeinated Beverage Intake (daily)	0	26% (5)
	1 to 2 drinks	32% (6)
	3 to 4 drinks	26% (5)
	5 or more drinks	16% (3)
Alcohol Intake (weekly)	Never	32% (6)
	Every other week	11% (2)
	1 to 2 days per week	42% (8)
	3 to 4 days per week	11% (2)
	More than 5 days per week	5% (1)
Tobacco Use (regular use in past month)	Yes	5% (1)
	No	95% (18)
Exercise Habits (daily)	Never	26% (5)
	1 to 2 days per week	32% (6)
	3 to 4 days per week	26% (5)
	More than 5 days per week	16% (3)
Shift Work (current)	Yes	63% (12)
	No	46% (7)
Sleep Characteristics		
History of a Sleep Disorder	Yes	16% (3)
	No	84% (16)
Chronotype	Morning	11% (2)
	Intermediate	74% (14)
	Evening	16% (3)
Use of Sleep Medication	Yes	47% (9)
	No	53% (10)
Use of Alerting Medication	Yes	5% (1)
	No	95% (18)

[a] The race/ethnicity category "other" consisted of individuals who identified as multi-racial (n=2) or did not identify their race/ethnicity on the survey (n=1).

for daytime work day, daytime day off, evening work day and evening day off, and sleep outcome measures. There were no statistically significant correlations between daily daytime or daily evening sunlight exposure and the examined sleep outcomes.

Table 5 presents mean (SD) and median (range) values for sleep outcome measures with regard to weekly daytime and weekly evening sunlight when comparing longer versus shorter durations of sunlight exposures. There was a statistically significant difference in median sleep duration ($p \leq 0.05$) based on the weekly longer (>45 h/week) versus shorter (<45 h/week) hours of daytime sunlight exposure. Longer daytime sunlight exposure was associated with a 102-min statistically significant decrease in median sleep duration compared to shorter sunlight exposure. Additionally, several sleep outcomes (insufficient sleep and sleep quality) were correlated at $r \geq .30$, though non-significantly, with longer (versus shorter) daytime sunlight exposure (workday and day off). There were no statistically significant differences in median sleep outcome measures when comparing longer (>16 h/week) versus shorter (<16 h/week) weekly evening sunlight exposure.

Table 2. Mean and median self-reported sleep outcomes[a] in Alaskan workers living in and/or near the Arctic Circle (n=19).

Sleep Outcomes	Mean ± SD	Median (Ranges)
Sleep Quality (PSQI score)	7.16 ± 3.82	6.0 (2.0–16.0)
Sleep Onset Latency (minutes)	29.32 ± 23.51	28.0 (1.0–90.0)
Sleep Duration (hours)	7.10 ± 1.51	7.0 (5.0–11.0)
Sleep Efficiency (%)	85% ± 14.86	89.5% (53–100%)
Insomnia Severity Index score	6.79 ± 3.90	7.0 (1.0–13.0)
Daytime Sleepiness (1–10 scale)	3.45 ± 1.46	3.0 (1.0–7.0)
Insufficient Sleep (days in past month)	8.39 ± 7.85	5.0 (2.0–31.0)

Abbreviations: PSQI, Pittsburgh Sleep Quality Index.
[a] Sleep outcomes were assessed via survey questions that asked participants to answer questions based on their typical sleep and sleep schedules over the past month.

Table 3. Pearson correlation coefficients [95% confidence intervals] between Sleep Hygiene Index scores and sleep outcomes[a] in Alaskan workers living in and/or near the Arctic Circle (n=19).

	Sleep Quality (PSQI Score)	SOL	Sleep Duration	SE[b]	ISI	Daytime Sleepiness	Insuff. Sleep
SHI	−.02 [−.47, .44]	−.10 [−.53, .37]	.12 [−.35, .54]	.18 [−.31, .60]	.25 [−.23, .63]	.62* [.23, .84]	.13 [−.34, .55]

Abbreviations: PSQI, Pittsburgh Sleep Quality Index; SOL, sleep onset latency; SE, sleep efficiency; ISI, Insomnia Severity Index; Insuff. Sleep, insufficient sleep; SHI, Sleep Hygiene Index.
[a] Sleep outcomes were assessed via survey questions that asked participants to answer questions based on their typical sleep and sleep schedules over the past month.
[b] n=18.
* Significant at the p≤.01 level.

Table 4. Pearson correlation coefficients [95% confidence intervals] for daily sunlight exposures and sleep outcomes[a] in Alaskan workers living in and/or near the Arctic circle (n=18).

	Day Sun (work)	Day Sun (off)	PM Sun (work)	PM Sun (off)
Sleep Quality	.39	.35	.07	.03
(PSQI Score)	[-.09, .72]	[-.14, .70]	[-.41, .52]	[-.44, .49]
Sleep Onset Latency	.33	.24	.26	.18
	[-.16, .69]	[-.26, .64]	[-.24, .65]	[-.31, .60]
Sleep Duration	-.32	-.35	.14	.14
	[-.68, .17]	[-.70, .14]	[-.35, .57]	[-35, .57]
Sleep Efficiency	-.14	-.04	.26	.28
	[-.58, .37]	[-.51, .45]	[-.25, .66]	[-.23, .67]
Insomnia Severity Index	.21	.21	.00	-.06
	[-.28, .62]	[-.28, .62]	[-.47, .47]	[-.51, .42]
Daytime Sleepiness	-.10	-.20	-.10	-.09
	[-.54, .38]	[-.61, .29]	[-.54, .38]	[-.53, .39]
Insufficient Sleep	.34	.30	.19	.15
	[-.15, .70]	[-.19, .67]	[-.30, .60]	[-.34, .58]

Longer (>45 h), versus shorter (<45 h), weekly hours of daytime sunlight exposure were found to be associated with a statistically significant decrease in median sleep duration. Although correlations between daily sunlight exposure and sleep outcomes were not statistically significant, there were several moderate strength correlations. These may be consistent with the significant findings for weekly daytime sunlight exposure and sleep duration indicating poorer sleep with increased daytime sunlight.

We did not find statistically significant associations between weekly evening sunlight exposure (longer versus shorter) with any sleep measures (Table 5). Additionally, there were only weak or absent correlations between daily measures of evening sunlight exposures and sleep outcomes, as for weekly evening sunlight exposures.

Discussion

Our findings indicate a high prevalence of poor sleep quality, increased sleep onset latency (SOL), as well as a widespread use of sleep aids among our sample of Arctic workers during a summer period of increased sunlight. Findings are consistent with previous research in Arctic and subarctic environments during the summer months [16,17]. The mean sleep quality score for the sample was above the clinical cut off (>5) [19], indicating poor sleep quality. Moreover, 53% of our sample individually met criteria for poor sleep quality. An average sleep onset latency (SOL) of approximately 29 min was reported in our Arctic sample, which is longer than the SOL of healthy adult sleepers, which is approximately 16 min [30]. Furthermore, approximately half of our sample reported the use of sleep aids, both prescribed and over the counter medications, during the past month. Our exploratory study of sleep during an Arctic summer is consistent with previous research in Arctic and subarctic environments identifying the occurrence of sleep disturbances during the summer months [16,17] and highlights the need for continued research to identify risk factors and protective factors associated with disturbed sleep in polar regions.

Beyond summarising a range of sleep measures in our sample of workers during an Arctic summer season, our study consisted of two primary aims: to examine the associations of sleep outcomes with sleep hygiene behaviours (Aim 1) and with sunlight exposure (Aim 2).

Table 5. Mean and median values of sleep outcomes[a] by weekly daytime and evening sunlight exposure duration (long versus short) in Alaskan workers living in and/or near the Arctic circle (n=18).

	Weekly daytime sunlight exposure [b]					Weekly evening sunlight exposure [c]				
	Long (>45 hrs) n=8		Short (<45 hrs) n=10			Long (>16 hrs) n=7		Short (<16 hrs) n=11		
Outcomes	Mean (SD)	Median (range)	Mean (SD)	Median (range)	Z (p)	Mean (SD)	Median (range)	Mean (SD)	Median (range)	Z (p)
Sleep Quality (PSQI Score)	8.6 (4.5)	7.0 (3.0–16.0)	5.9 (3.1)	5.0 (2.0–11.0)	−1.57 (0.12)	6.7 (3.2)	6.0 (3.0–13.0)	7.4 (4.5)	5.0 (2.0–16.0)	−0.14 (0.89)
Sleep Onset Latency (min)	35.1 (30.4)	35.0 (1.0–90.0)	24.6 (18.2)	20.0 (5.0–60.0)	−0.58 (0.56)	31.4 (29.0)	20.0 (5.0–90.0)	27.9 (22.1)	28.0 (1.0–60.0)	−0.23 (0.82)
Sleep Duration (hr)	6.4 (0.9)	6.3 (5.0–8.0)	7.8 (1.7)	8.0 (5.0–11.0)	−1.98 (0.05)	7.4 (1.8)	7.0 (6.0–11.0)	7.1 (1.4)	7.0 (5.0–8.5)	−0.05 (0.96)
Sleep Efficiency (%)	83.4 (17.6)	86.5 (53–100)	88 (14.6)	90 (54–100)	−0.44 (0.26)	91 (11.7)	94 (70–100)	82.3 (17.8)	87 (53–100)	−0.95 (0.34)
Insomnia Severity Index	7.8 (3.4)	7.0 (4.0–13.0)	5.8 (4.4)	5.0 (1.0–12.0)	−1.12 (0.26)	6.0 (4.0)	6.0 (1.0–12.0)	7.1 (4.1)	7.0 (1.0–13.0)	−0.55 (0.59)
Daytime Sleepiness	3.2 (1.4)	3.0 (1.0–6.0)	3.4 (1.4)	3.0 (2.0–7.0)	−0.15 (0.88)	3.2 (1.3)	3.0 (2.0–6.0)	3.4 (1.4)	3.0 (1.0–7.0)	−0.50 (0.62)
Insufficient Sleep	8.9 (6.2)	7.5 (2.0–20.0)	5.8 (5.3)	4.5 (2.0–20.0)	−1.08 (0.28)	7.6 (4.7)	8.0 (2.0–14.0)	6.8 (6.6)	4.0 (2.0–20.0)	−0.73 (0.46)

Abbreviations: PSQI, Pittsburgh Sleep Quality Index; Hrs, hours; Sleepiness, self-reported sleepiness (1–10 scale).
[a] Sleep outcomes were assessed via survey questions that asked participants to answer questions based on their typical sleep and sleep schedules over the past month.
[b] There were no exposures equal to 45.
[c] There were no exposures equal to 16.

While acknowledging the exploratory nature of this research, below we discuss our findings, their potential relevance, and potential limitations.

Sleep hygiene behaviours and sleep outcomes

The Sleep Hygiene Index (SHI) score was statistically significantly associated only with daytime sleepiness. Although this relationship was attenuated after adjustment for shift work, it remained moderate in strength, indicating that, as sleep hygiene worsened, daytime sleepiness increased, even after controlling for shift work. The correlation between sleep hygiene and insomnia symptoms was moderate in strength, though not statistically significant, which may indicate poorer sleep hygiene was associated with increased insomnia symptoms. All other associations between sleep hygiene scores and sleep measures indicated weak or absent relationships (r<.3), suggesting these were not related.

Our findings therefore suggest that sleep hygiene behaviours alone are not sufficient to improve sleep in Arctic environments. Findings are consistent with previous research. Friborg et al. [13] found that daily self-regulation behaviours, such as eating habits and physical activity, were not protective in modifying sleep across seasonal variations in their Arctic environment. Nevertheless, as poorer sleep hygiene was moderately correlated with increased sleepiness and insomnia symptoms, further research examining the associations between sleep hygiene behaviours and sleep during periods of increased light is needed.

Sunlight exposure and sleep outcomes

Longer (>45 h/week), versus shorter (<45 h/week), weekly daytime sunlight exposure, was statistically significantly associated with a median sleep duration decrease of 102 min (or, 1 h, 42 min). Across all other sleep outcome measures, the correlations, while non-statistically significant, were consistently in the direction of poorer sleep, with longer, versus shorter, weekly daytime sunlight exposure. Furthermore, regarding daily measures, as the hours of daily sunlight exposure increased, poor sleep quality increased, sleep duration decreased and insufficient sleep increased. These correlations were non-significant, but those for sleep quality and insufficient sleep were moderate in strength (r>.30), warranting further exploration in a larger sample. Evening sunlight exposure, when examined both daily and weekly, was not statistically significantly associated with any sleep outcomes; the correlations between daily evening sunlight exposure and sleep outcomes were weak or absent.

Our research adds to the literature on sleep during Arctic summers by examining natural light exposure during a period of increased day length. Findings indicated that during Arctic summers, increased daytime sunlight exposure (before 8 pm) was associated with poorer sleep outcomes. Light during the day is important for circadian entrainment. Our finding that long daytime sunlight exposure was associated with shorter sleep duration neither contradicts the possibility that underexposure to natural light may impair sleep nor does it contradict findings suggesting the entrainment benefits of daytime natural light. Rather, this suggests the importance of considering daytime/afternoon sunlight regulation in a 24-h light environment.

The impact of constant natural daytime light exposure on sleep and health is an area warranting more study. While a previous Arctic study found short natural light exposure to be a risk factor for insufficient sleep [9], this finding is not directly comparable to our study because Marqueze et al. [9] examined natural light exposure in Arctic samples during the winter. Our present study of an Arctic summer also examined daily and weekly daytime as well as evening natural sunlight exposures. Self-reported natural sunlight exposures for the Arctic and Brazilian samples in the study by Marqueze et al. [9] were significantly lower compared to the self-reported natural light exposures in our sample during a 24-h light environment in summer. Our findings suggest that longer exposure to natural sunlight before 8 pm may negatively influence sleep health in a 24-h natural light environment.

Very little is known about natural evening light exposure in a 24-h light environment due to limited research during summer in polar regions. Our findings regarding the lack of associations between evening sunlight exposure and sleep outcomes were unexpected and contrary to prior Arctic [24] and circadian research [31–34]. Researchers studying sleep over a 2-year time period at a Canadian Armed Forces Arctic base camp found that, after a base rule change affecting evening activities and prohibiting soldiers from leaving the base after 8 pm, sleep quality improved [24]. While not their primary study aim, the authors' findings also suggested that limiting evening sunlight exposure may have been related to the sleep quality improvements found in their sample. Additionally, circadian research findings suggest individuals are sensitive to artificial light stimuli during the night and exposure to artificial light in the evenings has been associated with sleep disturbances and circadian misalignment [31,33,34]. However, in our study, the number of hours of daily evening sunlight exposure and the weekly evening sunlight exposure duration (longer versus shorter exposure) were not associated with sleep outcomes.

There were no participants in our study reporting zero hours of light after 8 pm. Therefore, it may be that any amount of evening sunlight exposure is detrimental to sleep. While natural and artificial light during the biological night has been found to negatively affect sleep [24,31,33,34], we found that the amount of evening light after 8 pm was not associated with poorer sleep outcomes. Thus, the timing of light exposure, which we could not assess, may be a more relevant factor and warrants further study.

Limitations and strengths

Study limitations include our cross-sectional design, as the survey was administered at one point in time. While we could not examine sleep longitudinally, the uniqueness of the sample and setting, characterised by extreme seasonal shifts in photoperiods, enabled us to explore previously unexamined associations between sleep behaviours, sunlight and sleep outcomes. Our sleep outcomes, though self-reported, were based on reliable and valid measures. While we had data on the number of hours of sunlight exposure, we were unable to collect data on the intensity and timing of sunlight exposure beyond our operationalisation of sunlight before and after 8 pm. The influence of light on the circadian system depends on its timing [6] and intensity [32,35]. In other Arctic research, sunrise time rather than day length was found to be a stronger predictor of sleep length in residents of northern Russia [36]. Our operationalisation of sunlight prior to and after 8pm may not have captured the light's timing fully, and our self-reported measures could not address the intensity of light exposures. The artificial light environment and participants' exposure to artificial light in the evenings, which can influence sleep, were also not assessed.

In our study, shift work was associated with sleepiness and SHI scores; due to this, we adjusted for shift work in partial correlations with SHI scores. However, beyond these initial preliminary analyses, we were unable to include other descriptive variables, such as chronotype, in our analyses and examine further multivariate analyses due to the smaller sample size. Moreover, as our sample consisted primarily of "intermediate" chronotypes, given this lack of variability, in addition to the limited sample size, we were unable to examine chronotype other than descriptively. While our survey included a question on sleep disorder diagnosis, we did not have data on treatment of sleep disorders or on undiagnosed sleep disorders in our sample. Three respondents who reported a history of sleep apnoea were retained in the analyses; it is not possible to determine if the sleep disturbances that these individuals reported in our survey were influenced by their diagnosed sleep disorder and whether their sleep apnoea was treated or untreated.

A further limitation is that we did not adjust for multiple pairwise comparisons. While we recognise that correcting for multiple comparisons reduces the number of false positives, it may increase the number of false negatives, thus potentially missing important effects [37]. We believe that future research should consider our likely underpowered findings with the caution befitting exploratory studies and that they should be evaluated in studies with larger sample sizes.

While we did not calculate power a priori, in light of the limitations of a convenience sample and the exploratory nature of our study, we acknowledge our study was likely underpowered. For example, to detect medium or large effect sizes (based on estimated effect sizes of .3 and .5) [28] for 80% power and alpha of 0.05, we would have needed sample sizes of 82 or 26 participants, respectively, based on a G* Power calculation for Pearson R correlations [38]. We acknowledge the power limitations of our own convenience sample. For example, to detect a large effect size of .5 based on an estimated effect, not our own data, given the limitations of post-hoc power calculations [39], with an alpha of 0.05 in a sample of 19, the power would be estimated at only 66%. However, we wish to highlight that our study aim was to preliminarily explore these associations, rather than focus on statistical significance which can be further examined in future larger studies.

Our sample size, while smaller due to the exploratory nature of our study, is also comparable to sample sizes of other polar sleep studies in Arctic [17,24] and Antarctic [15,18] environments. Considering the exploratory nature of the present study and its smaller sample size, it may also be relevant to examine the relationships between study variables in the context of correlation coefficients, which has been done in our study. We thus presented correlation strengths and confidence intervals in addition to p-values. While our study sample may have more limited generalisability as we examined a small group of individuals working in and/or near the Arctic Circle in a remote area of north-eastern Alaska, this sample enabled us to investigate our aims of exploring sunlight exposure, sleep hygiene, and sleep outcomes in a 24-h light environment.

Conclusion

While our study is exploratory, we believe it contributes to the small body of literature on sleep in environments experiencing large seasonal variations in sunlight and may add to existing research on the prevalence of sleep disturbances throughout polar regions during summer months. The present study aimed to expand upon prior research by specifically examining sleep hygiene and self-reported sunlight exposure with respect to a range of sleep outcome measures. While sleep hygiene was correlated with sleepiness, this relationship was attenuated after controlling for shift work. Although there were no statistically significant correlations between self-reported daily sunlight exposures and sleep outcomes, increased daytime sunlight exposure was moderately correlated with a longer sleep latency, poorer sleep quality, decreased sleep duration and with insufficient sleep. There were no meaningful correlations found between daily evening sunlight exposure and the sleep outcomes examined. When sunlight exposure was examined on a weekly basis, longer, versus shorter, hours of evening sunlight exposure were not associated with any sleep measures. Longer weekly daytime sunlight exposure, versus shorter, was statistically significantly associated with decreased sleep duration in workers during an Arctic summer. Our findings from an Arctic summer are thus consistent with previous research [13], which has found that self-regulation behaviours alone are not protective against poor sleep in Arctic environments experiencing large seasonal shifts in sunlight.

Poor sleep characterises Arctic and subarctic human residents during both winter and summer seasons [11–14,16,17]. Thus, evidence-based recommendations are needed to help polar residents improve or maintain healthy sleep, especially during times of increased light or increased darkness. Our study focused on increased light as this has been under-examined to date. While sleep hygiene may improve daytime sleepiness, as shown in our study, sleep hygiene alone may not be sufficiently beneficial to protect sleep in a 24-h light environment. Further observational research is needed to identify additional protective factors for human sleep during periods of increased natural sunlight. In our study, shorter daytime light exposure was associated with longer total sleep time, and sleep hygiene behaviours were protective against sleepiness in Arctic workers.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The authors have not received any funding or benefits from industry or elsewhere to conduct this study.

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