Sleep and mood status and mental disorders during prolonged winter-over residence in two Korean Antarctic stations and their differences between two stations in different latitude

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Running title: Sleep status and mental disorder in Antarctica

Abstract

Purpose: Antarctica is a region with extreme climate, characterized by extreme cold and photoperiod. There has been insufficient research on this topic in the Korean Antarctic station. The aim of this study was to investigate the status of mental illness and changes in sleep and mood among Korean crew members staying for a long-term period in the Antarctic station.

Methods: From 2017 to 2020, crew members who were dispatched from South Korea to two Antarctic stations for a one-year period participated in this study. The crew were interviewed by board-certified psychiatrists once before departure and twice during their stay in Antarctica, and were evaluated for sleep and mood status and mental illness through psychological tests, including self-questionnaires. The incidence of mental illness was confirmed and changes in sleep and depression were analyzed.

Results: A total of 88 participants were included in the final analysis, and 7 of them (8.0%) were diagnosed with mental disorders such as insomnia in early winter. The total Beck Depression Inventory (BDI) score increased significantly in the early winter period, and the total Insomnia Severity Index (ISI) and Pittsburgh Sleep Quality Inventory (PSQI) scores increased in both early and late winter. The difference in changes in sleep and depression between the two stations was not significant.

Conclusion: This is the first study to investigate the mental illness and sleep and mood status of Korean crews dispatched to Antarctica. In early winter, there were significant increases in mental illness and depressive symptoms, and a worsening of sleep status.

Keywords: Antarctic, depression, insomnia, mental illness, sleep, winter-over

Introduction

Antarctica is a region with extreme climatic characteristics such as extreme coldness, unusual lengths of day and night, polar days and polar nights, severe storms, and low humidity. Although it is one of the seven continents and is vast enough to account for 10% of the Earth's land area, 98% of the entire surface of Antarctica is covered with perennial ice, and the temperature can drop to - 70 ℃ in winter, making it unsuitable for human habitation.[1] Antarctica is a very important region for the global environment because of its unique ecosystem, aquatic resources, natural gas deposits, and metal minerals. It is for this reason that it is known as a laboratory for scientific fields such as atmospheric science, meteorology, geology, and biology.[2] The Antarctic Treaty (1959) defined the area south of 60 degrees South latitude as Antarctica.[3]

Antarctica currently has more than 170 research stations operated by over 40 countries. Korea is the 16th country in the world to build a permanent research station in Antarctica: King Sejong Station on King George Island (West Antarctica) in 1988 and Jang Bogo Station in Terra Nova Bay (East Antarctica) in 2014. Changes in sleep and mood often occur during long-term residence in the Antarctic station as a result of the long duration of winter (more than 6-8 months), dispatch in isolation for more than 1 year, limited private space, monotony of lifestyle, and conflict with other personnel. Changes in sleep, insomnia, and mood disturbances such as depression, hostility, and irritability, also called winter-over syndrome, have been reported in

Antarctic crews.[4, 5] Therefore, previous studies on sleep disturbances and depression among Antarctic crews have been performed.[6]

Long-term Antarctic residence is thought to have a significant effect on human circadian rhythm and sleep-wake physiology; previous studies have reported changes in sleep quality and pattern, as well as decreased sleep duration in Antarctic overwinterers.[7-12] Studies have also been conducted on mood problems and depression caused by long-term residence in Antarctica.[7, 13, 14] Although many previous studies have reported that sleep problems and mood changes can occur in both the winter or summer period of Antarctica, some studies showed no obvious sleep disturbances or discrepancies in mood change according to the period, depending on the research method.[13, 15]

Long-term living in Antarctica can lead to mental illnesses. A study found that incidence of subsyndromal seasonal affective disorder (SAD) among Antarctic crews increased significantly from 10.5% in late summer to 28.4% in mid-winter.[16] In addition, a study investigating the incidence of mental illness among Antarctic crewmembers showed that 12.5% satisfied the diagnostic criteria of the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV).[17] Since intensive evaluation by a psychiatrist is required for a structured interview, the research on this is still considered inadequate.

Previous studies have suggested that cultural differences may influence the pattern of winter-over syndrome, but no study has been performed thus far from the Korean Antarctic

station. In addition, there is a big difference in the climatic environment, such as the duration of the winter period, photoperiod, and temperature between the stations within and outside the Antarctic circle (66.5 °south of the equator); therefore, it is an interesting research topic to investigate whether changes in sleep and mood differ between stations. However, only a small sample size study has been conducted on this.[18] Since the two Korean stations are located at different latitudes (King Sejong Station, 62° 13 39.4″ S; Jang Bogo Station, 74° 37 38″ S), the Korean stations are highly suitable sites for research on this subject.

The aims of this study were to investigate 1) the incidence of mental illness, 2) changes in sleep and mood while in Antarctica compared to before departure, and 3) the difference in changes in sleep and mood between the two Antarctic stations among Korean crew members staying in Antarctica for a one-year period.

Materials and methods

Participants

Information on the Antarctic stations is described in Table 1., showing location, altitude, weather-related information including temperature and photoperiod, animal and plant species, and indoor and living environments of the two Antarctic stations. The annual mean temperature of Jang Bogo Station (-15.1 C) is much lower than that of King Sejong Station (-1.8 C)

Antarctic crew members who were dispatched to the two stations annually from 2017 to 2020 by the Korea Polar Research Institute and stayed there for one year participated in the study. The crew consists of a researcher, facility maintenance staff, captain, and manager, with one medical doctor included under the category of management. These members underwent medical evaluation before deployment and had no serious medical, surgical, or psychiatric problems. Ethical approval for this study was granted by the Institutional Review Board (IRB) of Gil Medical Center (GCIRB2017-319), and all participants provided written informed consent.

Psychiatric and psychological evaluation methods

Antarctic crews usually entered Antarctica in November and left Antarctica in December the following year. All participants were evaluated for their mental and sleep status four times in total. For the first evaluation (before departure, September in South Korea), face-to-face

interviews with a board-certified psychiatrist, face-to-face psychological tests with a clinical psychologist, and self-questionnaire tests were conducted. In the second (early winter, mid-April in Antarctica) and third (late winter, late August in Antarctica) evaluation sessions, a video interview with a psychiatrist and a self-questionnaire were conducted. To maintain the consistency of the assessment, the psychiatric interview was conducted by the same board-certified psychiatrist as before. The fourth and final evaluation (after return, February in South Korea) was performed using a self-questionnaire.

All participants underwent face-to-face psychological tests and completed psychological self-questionnaires. The Rorschach test is a projective method of psychological testing that is widely used to assess emotional function, personality, and underlying thought disorders.[19] The Thematic Apperception Test (TAT) is a projective test to reveal an individual's perception of interpersonal relationships,[20, 21] in which thirty-one picture cards are shown as stimuli for descriptions of social situations and interpersonal relationships. The Sentence Completion Test (SCT) is a projective psychological test that examines self-image, conflicts or emotions, interpersonal relationships, and family relationships.[22] The Minnesota Multiphasic Personality Inventory (MMPI) is a standardized psychometric tool for personality and psychopathology.[23] In addition, the Beck Depression Inventory (BDI),[24] Beck Anxiety Inventory (BAI),[25] Mood Disorder Questionnaire (MDQ),[26] Alcohol Use Disorders Identification Test (AUDIT),[27] Insomnia Severity Index (ISI),[28] Pittsburgh Sleep Quality Inventory (PSQI),[29] and Stress

Questionnaire for Korea National Health and Nutrition Examination Survey-Short Form (SQ for KNHANES-SF),[30] which are measures to evaluate the degree of depression, anxiety, mood swing, drinking problem, insomnia, sleep quality, and quality of life, were performed, respectively. The BDI and BAI are measures to evaluate depression and anxiety, while the MDQ is a measure to screen for bipolar spectrum disorders.[24-26] The AUDIT is a screening tool to evaluate risky or hazardous alcohol use, and ISI is a measure to evaluate the severity of insomnia.[27, 28] The PSQI is a self-scale that evaluates sleep quality and can calculate measurements such as total score, sleep efficiency (SE), and total sleep time (TST).[29] The SQ for KNHANES-SF is a self-report questionnaire that evaluates individuals' level of stress and quality of life.[30]

For the first evaluation, a structured, face-to-face interview using DSM-5 was conducted by a psychiatris,[31] and psychological tests (Rorschach, TAT) were performed by a clinical psychologist through face-to-face interview.[19-21] The total time required for the face-to-face psychological tests and interview with the psychiatrist was approximately 3 hours. On the same day, participants also completed self-questionnaires (BDI, BAI, MDQ, MMPI, AUDIT, ISI, PSQI, and SQ for KNHANES SF) to examine psychological state, alcohol use, sleep, and quality of life. For the second and third evaluations, the board-certified psychiatrists assessed mental illness through a 30-to 60-minute video interview, and the participants were evaluated using the BDI, ISI, PSQI, and SQ for KNHANES-SF self-questionnaires. In the fourth and

final evaluation, participants were evaluated using the BDI, ISI, PSQI, and SQ for KNHANES-SF questionnaires.

Statistical Analysis

For inter-research station comparison, descriptive statistics, chi-square, and independent *t* test were used. A paired t-test was performed to investigate changes in BDI, ISI, and PSQI scores in the early winter, late winter, and after return periods compared to before departure. Linear mixed model analysis was performed to determine the differences in sleep and mood and the interaction between the two stations and each time point. Statistical analyses were performed at a two-sided significance level of $p < 0.05$. Statistical Package for the Social Sciences (SPSS, IBM Inc.) and R 4.1.3 were used for statistical analysis.

Results

Initially, 100 participants were recruited for the study, but six were not dispatched to Antarctica because of personal or health problems, five did not complete the questionnaire, and one withdrew their consent for the study. Finally, the data from 88 participants were included in the analysis. The average age of the subjects was 37.8 years.

Table 2 describes and compares the demographics and characteristics of the participants in the two Antarctic stations. There was no statistical difference in age, sex ratio, body mass index, marital status, type of work, and previous experience of winter-over in Antarctica between the two groups. However, as for winter-over experience, Jang Bogo Station showed a higher trend than King Sejong Station (32.6% vs 17.8%).

Table 3 describes the mental illness diagnosed by psychiatrists at each time point. No participant was diagnosed with mental illness before departure; however, in the early winter period, insomnia disorder (n = 3), adjustment disorder (n = 2), depressive disorder (n = 1), or alcohol use disorder (n = 1) was diagnosed. As a result, 7 participants (8.0% of the total) were diagnosed with mental illness; however, none of these constituted a condition that caused serious functional impairment in their work. In late winter, one participant was diagnosed with insomnia disorder, and the others recovered to a normal condition.

Table 3 shows the BDI, ISI, PSQI, and SQ for KNHANES-SF scores at each time point and indicates whether there was a significant change in the later period compared to before

departure. The BDI total score increased in early winter, and the ISI total score increased in early winter, late winter, and after return compared to baseline. The PSQI total score increased in early winter and late winter, and the TST of PSQI decreased in late winter compared to baseline. The SE of the PSQI decreased in all phases of early winter, late winter, and after return compared to before departure. The SQ for KNHANES-SF showed an increased total score in late winter compared to baseline.

Table 4 presents the results of analysis of difference in mood and sleep status among the stations and the measurement time point, and the interaction between the station and the measurement time point. Multiple testing corrections through Bonferroni correction were performed for the results that showed statistically significant differences (Supplementary Tables S1 and S2). Table 4 shows that there was no significant interaction effect between the station and the measurement time point, and there were significant changes in the ISI total score and PSQI SE according to time within one station, as well as a difference in the BDI total score between the stations at one time point (Table 4). Even after adjusting for multiple testing, there was a significant difference in the BDI total score between the two stations in late winter and after return (Supplementary Table S1). Further, after the correction of multiple testing comparison, there was a significant difference in the ISI total scores in early winter and late winter at King Sejong station compared to before departure (Supplementary Table S2). After adjusting for multiple testing, there was a significant difference in the ISI total score in early

winter and late winter compared to before departure, and there was a significant difference in PSQI sleep efficiency between before and after departure at Jang Bogo Station (Supplementary Table S2).

Discussion

The main result of this study was that mental illnesses such as insomnia disorder, adjustment disorder, depressive disorder, and alcohol use disorder occurred in the early winter among the Korean Antarctic crew. In the self-administered questionnaire, depression worsened in the early winter period, while insomnia and sleep quality worsened in both early and late winter. The differences in mood and sleep changes between the two groups were not significant.

Although the mental illness of the Antarctic crew did not cause serious functional impairment, 8.0% of the crew members developed mental illness (including insomnia disorder, adjustment disorder, depressive disorder, and alcohol use disorder), which was most prevalent in early winter, and then mostly recovered in late winter. The incidence of mental illness in this study was between the prevalence of 12.5% reported in a previous study and the weighted prevalence of 5.2% among the United States Antarctic Program using DSM-IV disorders.[17] The reason for the improvement in mental illness in late winter is presumed to be that the crew has adjusted to life in Antarctica, that it will not be long before return to their hometown, and that the crew members with severe psychiatric symptoms were able to take psychotropic medication, including antidepressants and light therapy, under the doctor's prescription at the research station. Regarding the change of symptoms according to the period of winter, the classical concept is that the symptoms of winter-over syndrome peak in mid-winter,[32] however, the change pattern differs between studies, with some individuals showing a decrease in psychiatric

symptoms during early to late winter.[33] In a previous study, sleep disturbance showed a significant correlation with the severity of the climate in early winter, but this significant relationship disappeared in late winter.[33] This is attributed to gradual adaptation to the environment.

Depression scores increased significantly in early winter compared to before departure, although it was not at a level that could be considered a clinical problem and decreased in late winter to a level similar to before departure. In a previous study conducted on U.S. station personnel, the depression score measured using the Profile of Mood States (POMS) of winter-over staff in the South Pole decreased in later winter compared to that in early winter.[34]

In this study, insomnia and sleep quality deteriorated in both early and late winter. In the previous studies, long-term residents in Antarctica showed shallow nighttime sleep, frequent awakening, increased sleep latency, and increased insomnia and daytime sleepiness.[35, 36] It is reported that sleep disturbances are usually severe in winter and have been attributed to harsh weather, polar nights, and emotional and psychological reactions to isolation.[37] As a result of the study conducted at the Antarctic Station in India, the TST and SE significantly decreased and the waking period after sleep onset of polysomnography increased in winter compared to before departure from India.[12] In this study, the SE of PSQI decreased not only during winter in Antarctica, but also during the after-return period. This was probably due to the long journey home, jet lag, and irregular sleeping habits after returning.

In this study, there were no differences in the changes in depression and sleep between stations. A study previously conducted with the Chinese Antarctica crew showed a greater increase in anger at Zhongshan Station located at 66° S compared to Great Wall Station located at 62° S.[18] Table 1 shows significant difference in annual mean temperature between King Sejong Station and Jang Bogo Station (-1.8 °C vs -15.1 °C, respectively) due to the latitude difference and also a large difference in the photoperiod (no polar day and polar night in King Sejong Station vs. polar day and polar night in Jang Bogo Station). Despite the large climatic difference between the two Korean stations, the reason for the lack of differences in changes in depression and sleep between the stations might be the characteristics of the two groups, as shown in Table 2. The proportion of those with winter-over experience tended to be higher at Jang Bogo Station, although there was no significant difference in the demographic characteristics between the two stations. This is thought to be because Jang Bogo Station is usually considered a more difficult station to adapt to; therefore, more crews with past Antarctic experience were deployed to Jang Bogo Station. Past experience of working in Antarctica may have helped the crew cope with worsening mood and sleep. Since the number of participants at the two stations in this study was relatively small, for a more accurate comparison between the stations, a larger study should be conducted with the same crew demographics and characteristics in the future.

Conclusion

In summary, the crew who stayed in Antarctica for a long-term period developed mental illnesses such as insomnia and depression during the winter. Factors such as harsh weather, extreme photoperiod, and isolation during their stay in Antarctica may have affected sleep and mood deterioration. For future research, it is suggested that changes in sleep and mood be tracked during the entire year of stay, with more participants involved and the incorporation of an objective sleep measurement device.

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Disclosure

The authors report no conflicts of interest associated with this work.

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TABLES

Table 1. Characteristics of the two Korean Antarctic stations

Characteristics	King Sejong Station	Jang Bogo Station
Location	62° 13′ 39.4″ S, 8° 47′ 19.0″ W	74° 37′ 38″ S, 164° 1′ 16″ E
Altitude	9.85 M	36.6 M
Weather		
Temperature		
Annual mean temperature	-1.8 ℃	-15.1 ℃
Minimum – maximum and average temperature in each month		
January	-2.2 ℃ – 7.6 ℃, 1.6 ℃	-7.7 ℃ – 2.4 ℃, -1.9 ℃
February	-3.9 ℃ – 8.5 ℃, 1.5 ℃	-11.6 ℃ – -1.0 ℃, -6.6 ℃
March	-8.0 ℃ – 8.1 ℃, 0.9 ℃	-18.7 ℃ – -8.2 ℃, -13.6 ℃
April	-9.7 ℃ – 6.9 ℃, -0.7 ℃	-25.0 ℃ – -12.2 ℃, -19.2 ℃
May	-12.1 ℃ – 5.0 ℃, -2.6 ℃	-27.7 ℃ – -14.5 ℃, -22.2 ℃
June	-13.3 ℃ – 2.8 ℃, -4.0 ℃	-28.3 ℃ – -14.5 ℃, -21.8 ℃
July	-16.4 ℃ – 3.2 ℃, -4.1 ℃	-28.0 ℃ – -12.3 ℃, -20.5 ℃
August	-16.1 ℃ – 3.9 ℃, -5.5 ℃	-28.4 ℃ – -12.6 ℃, -22.5 ℃
September	-15.8 ℃ – 5.0 ℃ / -4.1 ℃	-28.7 ℃ – -14.1 ℃ / -22.0 ℃
October	-12.7 ℃ – 5.5 ℃ /-2.5 ℃	-22.7 ℃ – -6.6 ℃ / -15.5 ℃
November	-5.4 ℃ – 6.1 ℃ / -0.2 ℃	-10.1 ℃ – -3.4 ℃ / -6.7 ℃
December	-3.2 ℃ – 6.8 ℃ / 0.8 ℃	-4.4 ℃ – 1.1 ℃ / -1.5 ℃
Winter period	April – September	March – October
Summer period	October – March	November – February
Photoperiod	No polar day and no polar night	Polar day: 2nd Nov – 9th Feb Polar night: 5th May – 7th Aug
Animals and plants	Animals: Penguin, seal, gull, and whale	Animals: Penguin, seal, and gull Penguin and gull disappear in

	Plants: Moss	winter No plants
Indoor and living environments of station		
Number of persons (During winter / Maximum capacity)	18 persons / 78 persons	18 persons / 80 persons
Accommodations	Single room with bathroom	Single room with bathroom
Food and beverages	Cereal, meat, vegetables, and fruit	Cereal, meat, vegetables, and fruit from May to December
Telecommunication	Telephone and Internet	Telephone and Internet
Social activities	(Before 2020) Antarctic Olympic games, friendly official party (From 2020) No activity because of COVID19 pandemic	(Before 2020) Friendly official party (From 2020) No activity because of COVID19 pandemic
Anniversary	Korean Thanksgiving Day, Lunar New Year's Day, and mid-winter greeting	Korean Thanksgiving Day, Lunar New Year's Day, and mid-winter greeting

The above information is for the period 2018 - 2020 when the participants were in Antarctica.

Table 2. Demographic and characteristics of participants before departure and comparisons between the two stations

Variables		King Sejong Station (n =45)	Jang Bogo Station (n =43)	Statistics
Age, years		38.5 ± 8.3	37.1 ± 8.7	t = -0.76, p = 0.451
Sex, male		43 (93.3%)	43 (100%)	x^2 = 2.97, p = 0.242
Body mass index (BMI)		24.9 ± 2.7	24.2 ± 1.7	t = -1.64, p = 0.106
Marital status, married		23 (51.1%)	24 (57.1%)	x^2 = 0.32, p = 0.573
Type of work	Captain and manager	10 (22.2%)	9 (20.9%)	
	Research	14 (31.1%)	16 (37.2%)	x^2 = 2.17, p = 0.538
	Facility maintenance	19 (42.2%)	18 (41.9%)	
	Unknown	2 (4.4%)	0 (0%)	
Winter-over				
Winter-over experience (+)		8 (17.8%)	14 (32.6%)	x^2 = 2.56, p = 0.109
Total winter-over experience, months		4.2 ± 10.7	6.0 ± 10.1	t = 0.82, p = 0.414

Data are presented as mean ± standard deviation or number (percentage).

Table 3. Mental illness and sleep and mood states and their changes from baseline among all participants

Variables	Before departure	Early winter	Late winter	After return
Mental disorders				
Adjustment disorder	0 (88, 0%)	2 (88, 2.3%)	0 (88, 0%)	
Depressive disorder	0 (88, 0%)	1 (88, 1.1%)	0 (88, 0%)	No face-to-face interview
Insomnia disorder	0 (88, 0%)	3 (88, 3.4%)	1 (88, 1.1%)	
Alcohol use disorder	0 (88, 0%)	1 (88, 1.1%)	0 (88, 0%)	
BDI	1.4 ± 2.7 (87)	2.1 ± 2.8 (87) t = -2.13, ***p* = 0.036**	1.5 ± 2.5 (87) t = -0.53, p = 0.599	1.6 ± 2.6 (83) t = -0.67, p = 0.507
ISI	1.5 ± 2.1 (88)	3.5 ± 4.2 (88) t = -4.74, ***p* < 0.001**	3.1 ± 3.6 (88) t = -4.18, ***p* < 0.001**	2.4 ± 3.8 (85) t = -2.27, ***p* = 0.025**
PSQI				
Total score	3.5 ± 2.0 (88)	4.7 ± 2.8 (88) t = -3.59, ***p* = 0.001**	4.6 ± 2.5 (88) t = -3.96, ***p* < 0.001**	5.2 ± 10.7 (74) t = -1.45, p = 0.151
Total sleep time	399.8 ± 67.2 (88)	388.5 ± 65.6 (88) t = 1.35, p = 0.182	381.9 ± 64.8 (88) t = 2.26, ***p* = 0.026**	395.5 ± 74.1 (75) t = 0.58, p = 0.565
Sleep efficiency	94.2 ± 6.0 (88)	91.0 ± 10.9 (88) t = 2.75, ***p* = 0.007**	91.4 ± 10.7 (88) t = 2.44, ***p* = 0.017**	89.4 ± 16.3 (74) t = 2.86, ***p* = 0.005**
SQ for KNHANES-SF	10.4 ± 2.7 (88)	10.9 ± 2.5 (88) t = -1.69, p = 0.094	11.3 ± 3.5 (86) t = -2.07, ***p* = 0.042**	11.2 ± 4.3 (75) t = -1.89, p = 0.063

Mental disorders are presented as number of subjects with mental disorder (number of total participants, percentage of mental illness)

Scale data are presented as mean ± standard deviation (number of participants).

Before departure was September in South Korea. Early winter and late winter was mid-April and late August in Antarctica, respectively. After return was February in South Korea.

Paired *t*-test was used (before departure vs early winter, before departure vs late winter, before departure vs after return). Bold indicates clinical significance ($p < 0.05$).

Abbreviations: BDI, Beck Depression Inventory; ISI, Insomnia Severity Index; PSQI, Pittsburgh Sleep Quality Index; SQ for KNHANES-SF, Stress Questionnaire for Korea National Health and Nutrition Examination Survey-Short Form

Table 4. Comparison of the sleep and mood states between the stations and time points

Comparison variables	King Sejong Station	Jang Bogo Station	Linear mixed models		
	Mean (SE [95% CI], N)	Mean (SE [95% CI], N)	Effect	F	p-value
BDI					
Before departure	1.78 (0.50 [0.81-2.75], 45)	0.95 (0.28 [0.41-1.50], 42)	Time	2.233	0.085
Early winter	2.60 (0.45 [1.72-3.48], 45)	1.67 (0.38 [0.93-2.42], 43)	Station	9.592	**0.003**
Late winter	2.29 (0.46 [1.38-3.20], 45)	0.74 (0.20 [0.35-1.14], 43)	Time: Station	0.722	0.540
After return	2.28 (0.49 [1.33-3.23], 43)	0.76 (0.24 [0.29-1.22], 41)			
ISI					
Before departure	1.69 (0.33 [1.05-2.33], 45)	1.30 (0.32 [0.68-1.93], 43)	Time	10.650	**< 0.001**
Early winter	4.02 (0.63 [2.79-5.26], 45)	2.93 (0.63 [1.70-4.16], 43)	Station	1.454	0.231
Late winter	3.53 (0.59 [2.38-4.69], 45)	2.61 (0.48 [1.67-3.54], 43)	Time: Station	0.427	0.734
After return	2.64 (0.60 [1.47-3.80], 44)	2.15 (0.59 [1.00-3.29], 41)			
PSQI total score					
Before departure	3.47 (0.29 [2.90-4.03], 45)	3.63 (0.31 [3.02-4.23], 43)	Time	1.510	0.213
Early winter	4.64 (0.41 [3.84-5.45], 45)	4.70 (0.44 [3.84-5.56], 43)	Station	1.419	0.237
Late winter	4.78 (0.38 [4.04-5.51], 45)	4.51 (0.39 [3.76-5.27], 43)	Time: Station	1.758	0.156
After return	6.77 (2.44 [1.99-11.55], 37)	3.65 (0.44 [2.79-4.51], 37)			
PSQI total sleep time (min)					
Before departure	403.60 (7.89 [388.10-419.10], 45)	395.80 (12.20 [371.90-419.70], 43)	Time	2.103	0.100
Early winter	390.10 (9.43 [371.60-408.60], 45)	386.70 (10.48 [366.20-407.30], 43)	Station	0.002	0.965

Late winter	379.40 (10.43 [359.00-399.90], 45)	384.40 (9.11 [366.60-402.30], 43)	Time: Station	0.432	0.730
After return	391.80 (13.50 [365.30-418.20], 37)	399.20 (10.76 [378.10-420.30], 38)			
PSQI sleep efficiency (%)					
Before departure	93.58 (0.84 [91.92-95.23], 45)	94.91 (0.95 [93.04-96.78], 43)	Time	4.435	**0.005**
Early winter	90.61 (1.82 [87.04-94.17], 45)	91.49 (1.44 [88.68-94.30], 43)	Station	2.363	0.128
Late winter	89.53 (1.77 [86.06-93.00], 45)	93.40 (1.38 [90.70-96.10], 43)	Time: Station	0.776	0.508
After return	87.60 (3.48 [80.79-94.41], 37)	91.28 (1.50 [88.33-94.22], 37)			
SQ for KNHANES-SF					
Before departure	10.69 (0.47 [9.77-11.61], 45)	10.12 (0.30 [9.52-10.71], 43)	Time	2.117	0.099
Early winter	11.09 (0.38 [10.34-11.83], 45)	10.70 (0.39 [9.93-11.46], 43)	Station	2.056	0.155
Late winter	11.54 (0.58 [10.39-12.68], 43)	11.07 (0.49 [10.11-12.03], 43)	Time: Station	0.916	0.434
After return	11.89 (0.88 [10.16-13.62], 37)	10.45 (0.44 [9.59-11.30], 38)			

Data are presented as mean (standard error [95% confidence interval], number of participants).

The comparisons of the sleep and psychological states between the two groups and time points were performed using the linear mixed models.

Bold indicates clinical significance ($p < 0.05$).

Before departure was September in South Korea. Early winter and late winter were mid-April and late August in Antarctica, respectively. After return was February in South Korea.

Abbreviations: BDI, Beck Depression Inventory; ISI, Insomnia Severity Index; N, number of participants who completed the questionnaire; PSQI, Pittsburgh Sleep Quality Index; SQ for KNHANES-SF, Stress Questionnaire for Korea National Health and Nutrition Examination Survey-Short Form

Supplementary Table S1. Two-sample *t*-test with Bonferroni correction of BDI total score between stations

Comparison variables	N1	N2	*F*-test		*t*-test	
			F statistics	Adjusted *p*-value	T-statistics	Adjusted *p*-value
BDI						
Before departure	45	42	0.295	< 0.001	-1.450	0.608
Early winter	45	43	0.678	0.836	-1.566	0.484
Late winter	45	43	0.179	< 0.001	-3.067	**0.013**
After return	43	41	0.226	< 0.003	-2.823	**0.026**

For variables that were significant in the LMM results in Table 4, homogeneity of variance test using the F-test and a post hoc test using the *t*-test according to results of the homogeneity of variance test were performed. Two-sample *t*-test was performed for early winter where equal variance was established, and Welch's two-sample t-test was performed for cases where equal variance was not established.

Bold indicates clinical significance ($p < 0.05$).

N1 = number of participants who completed questionnaires in the King Sejong Station; N2 = number of participants who completed questionnaires in the Jang Bogo Station.

Abbreviations: BDI, Beck Depression Inventory; LMM, linear mixed model

Supplementary Table S2. Paired *t*-test with Bonferroni correction of ISI total score and sleep efficiency of PSQI between each time point

Comparison variables	N	T statistics	Adjusted p-value
ISI at King Sejong Station			
Before departure vs Early winter	45	-3.761	**< 0.001**
Before departure vs Late winter	45	-2.839	**0.042**
Before departure vs After return	44	-1.435	0.954
Early winter vs Late winter	45	1.302	1
Early winter vs After return	44	2.947	**0.03**
Late winter vs After return	44	2.436	0.114
ISI at Jang Bogo Station			
Before departure vs Early winter	43	-2.887	**0.036**
Before departure vs Late winter	43	-3.507	**0.006**
Before departure vs After return	41	-1.870	0.414
Early winter vs Late winter	43	0.611	1
Early winter vs After return	41	1.345	1
Late winter vs After return	41	0.805	1
PSQI SE at King Sejong Station			
Before departure vs Early winter	45	1.609	0.690
Before departure vs Late winter	45	2.215	0.192
Before departure vs After return	37	1.730	0.552
Early winter vs Late winter	45	0.732	1
Early winter vs After return	37	1.966	0.342
Late winter vs After return	37	1.060	1
PSQE SE at Jang Bogo Station			
Before departure vs Early winter	43	2.432	0.114
Before departure vs Late winter	43	1.096	1

Before departure vs After return	37	3.384	**0.012**
Early winter vs Late winter	43	-1.340	1
Early winter vs After return	37	0.120	1
Late winter vs After return	37	0.802	1

Post-hoc *t*-test results only for the variables that were significant in the linear mixed model analysis in Table 4

Bold indicates clinical significance ($p < 0.05$).

Abbreviations: ISI, Insomnia Severity Index; N, number of subjects who completed the questionnaire; PSQI, Pittsburgh Sleep Quality Index, SE, sleep efficiency