

# Cross-Lagged Panel Networks of Sleep Inertia Across Its Distinct Change Patterns Among Intern Nurses with Shift Work in China

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**Purpose:** Although experimental psychopathology using PET, EEG, and fMRI is at the forefront of understanding the underlying mechanisms of sleep inertia, many questions concerning causality remain unanswerable due to ethical constraints and the use of small and heterogeneous samples in experimental methods. There is a pressing need for a novel perspective in a large and relatively homogeneous population to fully capture and elucidate longitudinal processes and dynamic causality that culminate in episodes of sleep inertia over time. Therefore, this study aimed to reveal the causal relationships between symptoms of sleep inertia across its distinct patterns.

**Patients and Methods:** A total of 1636 intern nurses participated in the first survey (94.1% validity rate), then 1277 intern nurses were followed up (82.9% tracing rate). Symptoms of sleep inertia were self-reported using the Sleep Inertia Questionnaire. The cross-lagged panel network models were used to examine unique longitudinal relationships between symptoms of sleep inertia across distinct trajectories.

**Results:** Four distinct trajectories of sleep inertia were established. Additionally, we found differences in those symptoms with the highest influence on other symptoms at the subsequent point across the networks of four trajectories, particularly, "Difficulty in concentrating" in the persistent-high group and "Feeling tense" in the deteriorating groups.

**Conclusion:** The current study highlights changes in sleep inertia based on the long-term course over time. Notably, symptoms of "Difficulty in concentrating" and "Feeling tense" are imperative to address these specific symptoms within subpopulations.

**Keywords:** sleep inertia, change patterns, network structures, intern nurse, shift work

## Introduction

Sleep inertia, characterized by temporarily degraded vigilance, impaired neurobehavioral cognitive performance, worsened mood, and sleepiness, is the unavoidable transitional state from sleep to wakefulness.<sup>1-3</sup> Individuals with sleep inertia while performing safety-critical tasks are at greater risk of performance errors or accidents, posing threats to the safety of themselves and those around them.<sup>1,4,5</sup> For example, on May 29, 2010, the 3252gt Norwegian-registered platform supply vessel (Skandi Foula) made heavy contact with the moored Panamanian-registered supply vessel (OMS Resolution) in Victoria Dock, Aberdeen.<sup>4</sup> Analysis of the chief officer's hours of rest suggested that he was suffering from sleep inertia at the time of the accident, which may have impaired his ability to control Skandi Foula effectively.<sup>4</sup> Furthermore, the prevalence rates of severe sleep inertia increased from 2.9% in 2000 to 15.2% in 2014 among the

general population.<sup>6,7</sup> Notably, a sample of 92 employed and volunteer Australian emergency service personnel completed an online survey to determine whether sleep inertia is perceived as a concern among emergency service personnel.<sup>8</sup> Results found that 25% of shift workers reported that, despite having the opportunity to nap or rest while on shift, they chose not to nap to avoid sleep inertia.<sup>8</sup> Given the increasing prevalence of severe sleep inertia and the extensive demands of 24/7 service, it is essential to deepen our understanding of sleep inertia to minimize its potential risks for emergency service personnel.

Decades of research using PET, EEG, and/or fMRI have investigated the neurophysiological mechanisms of sleep inertia.<sup>9–13</sup> To illustrate, a simultaneous EEG-fMRI study has revealed that sleep-like features such as slow EEG power and reduced BOLD activity persist during sleep inertia.<sup>9</sup> Vallat et al found that awakening in deep sleep is characterized by a global loss of brain functional segregation between task-negative (default mode) and task-positive (dorsal attention, salience, sensorimotor) networks.<sup>10</sup> Although experimental psychopathology using PET, EEG, and fMRI is at the forefront of understanding the underlying mechanisms of sleep inertia, many questions concerning causality remain unanswerable due to ethical constraints and the use of small and heterogeneous samples in experimental methods. Notably, as a complement to experimental approaches, network analysis aims to clarify the causal processes among symptoms that culminate in episodes of psychological phenomena or disease using data from large-scale self-report surveys.<sup>14,15</sup>

Recently, the network analysis based on network theory has emerged as an alternative framework for conceptualizing mental disorders and psychological phenomena.<sup>16,17</sup> Network theory posits that symptoms of psychopathology are causally connected through various biological, psychological, and societal mechanisms. When these causal associations are sufficiently strong, symptoms may generate feedback loops that sustain themselves.<sup>17</sup> While undirected networks with cross-sectional data have involved correlational analyses,<sup>15</sup> the cross-lagged panel network (CLPN) could illuminate longitudinal processes and dynamic causality occurring within and across constructs over time.<sup>18,19</sup> This approach is well-suitable for elucidating the causal associations between symptoms proposed by the network theory.<sup>18,20</sup> Network parameters, such as edges and thresholds, are statistical representations of psychological and biological processes, derived from material referents in the real world.<sup>14</sup> In brief, network analysis could identify connections that appear consistently across many people, which may provide some leverage for thinking about innovative prevention strategies in the real world.<sup>14</sup>

In summary, by using longitudinal data, we would like to employ CLPN to uncover the temporal and causal relationships between symptoms of sleep inertia. Notably, several studies have highlighted significant individual differences in people's responses and adaptation processes to sleep inertia,<sup>2,8,21,22</sup> indicating that there may be distinct change patterns of sleep inertia over time. Therefore, the current study aimed to deepen our understanding of sleep inertia across these varied change patterns.

## Materials and Methods

### Participants

Participants were recruited from a nursing school in Huizhou, China. The sample size was calculated according to established formula:<sup>23</sup>

$$N = \frac{Z_{1-\alpha/2}^2 pq}{d^2}$$

In the above formula,  $p$ ,  $d$ , and  $Z_{1-\alpha/2}$  represents the expected minimum rate by a previous study,<sup>6</sup> allowable error, and statistic for significance test.<sup>23</sup> Specifically,  $p = 0.152$ ,  $q = 1 - p = 1 - 0.152 = 0.848$ ,  $d = 0.2p = 0.2 * 0.152 = 0.0304$ ,  $Z_{1-\alpha/2} = 1.96$ . According to this formula, the minimum required sample size for this study is 536 people. To accommodate potential missed responses, refusals, and dropout risks during a longitudinal study, the sample size was adjusted to a ratio of 1:2.

This study included two surveys: the first survey (Time 1, T1) was conducted half a month after their clinical internship from June 28 to July 5, 2022) and the second wave (Time 2, T2) occurred three and a half months later from October 11 to 31, 2022. In the first survey, 1636 intern nurses participated, with 1540 providing valid questionnaires (94.1% validity rate). For the second survey, 1277 intern nurses were followed up (82.9% tracing rate), and, 1156

successfully completed all measurements. After excluding 77 individuals with day work, the current study included 1079 intern nurses with shift work.

## Procedure

An electronic invitation letter including a QR code for the questionnaire, was initially sent to the target population via their teachers. The participants volunteered to complete the online questionnaires via their phones or computers with the assistance of trained staff from the nursing school. All participants were free to withdraw from the study at any time. If they feel uncomfortable during or after participating in this study, they could get psychological counseling services from South China Normal University (SCNU) according to the contact information we provided. We assessed various variables in both surveys, including demographic characteristics, willingness to continue working as a nurse, circadian rhythm, sleep inertia, sleep problems, and emotional problems. Electronic informed consent was obtained from all participants or their guardians (if necessary) before starting this survey. Our study was approved by the Human Research Ethics Committees of SCNU and carried out in line with the Helsinki Declaration as revised in 1989.

## Measures

The subjective sleep inertia over the past week was assessed by the Chinese version of the Sleep Inertia Questionnaire (SIQ) in both surveys.<sup>24</sup> Previous studies demonstrated that the SIQ has robust reliability and validity among different populations.<sup>24,25</sup> Each item of the SIQ is rated on a 5-point Likert scale (1 = Not at all, 2 = A little, 3 = Somewhat, 4 = Often, 5 = All the time). With a total of 21 items, the SIQ yields scores ranging from 21 to 105, where higher scores indicate more severe sleep inertia. The cut-off score of 69 indicates severe sleep inertia in the current sample. Another study, currently under review in the *Journal of Sleep Research*, offers a more detailed analysis of the cut-off score of 69 used to classify severe sleep inertia among intern nurses. The Cronbach's  $\alpha$  for the SIQ in this study were 0.95 at T1 and 0.96 at T2, respectively.

Sex, subjective sleep quality at T1, and sleep duration at T1 were evaluated separately using single items. The morningness–eveningness type was determined at T2 through the Chinese version of the 5-item Morningness/Eveningness Questionnaire (MEQ-5).<sup>26</sup> The two dimensions (flexibility and languid) of the Chinese Version of the Circadian Type Inventory (CTI) were used to measure the flexibility of the rhythm (items 1–6) and the ability to overcome drowsy (items 7–11), respectively.<sup>27</sup>

## Statistical Analyses

### Change Patterns of Sleep Inertia

The change patterns of sleep inertia were disentangled based on the following two steps. Firstly, participants were classified into non- or severe sleep inertia with a cut-off value of 69 at T1 and T2, respectively. Second, the change patterns of sleep inertia from T1 to T2 after their clinical internship were revealed according to the methodology of previous research.<sup>28,29</sup> We further summarized four patterns of sleep inertia: persistent-low, alleviating, deteriorating, and persistent-high. More specifically, individuals in the persistent-high group showed severe sleep inertia at both time points. Intern nurses who reported no severe sleep inertia at T1 but symptoms at T2 were assigned to the deteriorating group. Participants with severe sleep inertia at T1 but without symptoms at T2 were included in the alleviating group. For the persistent-low group, severe sleep inertia was absent at both time points.

### The Cross-Lagged Panel Network Models

The CLPN models were constructed using a series of regularized regression models to estimate both the autoregressive and cross-lagged coefficients. The autoregressive coefficients depict a variable's influence on itself at the subsequent measurement after controlling for covariates, while the cross-lagged coefficients illustrate the influence of one variable on another variable at the subsequent measurement.<sup>19</sup> Demographic and sleep-related factors (see [Supplementary Table 1](#)) were incorporated as covariates in all CLPN models, as recommended by Funkhouser et al.<sup>18</sup> All models were estimated using the R-package *glmnet*, and all network graphs were visualized using the *Fruchterman-Reingold* algorithm in R-package *qgraph*. In a network

graph, nodes represent the symptoms, edges depict the relationships between two symptoms, and the thickness of the edges represents the strength of associations between symptoms.<sup>30</sup>

Centrality indices, namely the in-expected influence (in-EI) and out-expected influence (out-EI), were computed using the R-package *qgraph*.<sup>30</sup> The in-EI quantifies the proportion of variance for a given variable at follow-up that is accounted for by nodes at baseline, whereas the out-EI signifies the effect a given node at baseline has on nodes at follow-up.<sup>18,31,32</sup> As in previous studies,<sup>33,34</sup> the threshold for identifying key symptoms was set at in-EI > 1 and out-EI > 1.

The bootstrapping function in the R-package *bootnet* was utilized to evaluate the accuracy and stability of all networks.<sup>35</sup> First, we employed nonparametric bootstrapping to examine the edge-weight accuracy and the significance between edge-weights, with 95% confidence intervals (CIs) based on 1000 bootstrap iterations. Then, we calculated the correlation stability coefficient (CS-C) using the case-dropping bootstrap procedure. The CS-C quantifies the maximum proportion of cases that can be dropped while maintaining a correlation above 0.7 between the centrality indices of the sample with and without dropouts with 95% possibility. The CS-C values  $\geq 0.25$  were considered acceptable, whereas CS-C values  $\geq 0.50$  were regarded as good.

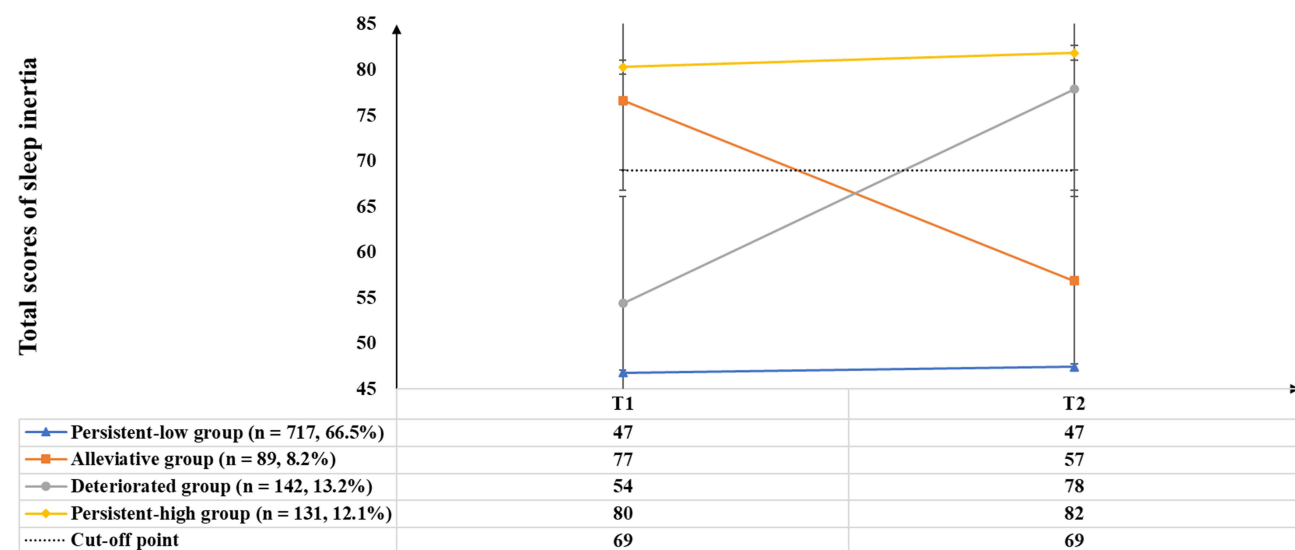
## Results

### Change Patterns of Sleep Inertia

As shown in Figure 1, four distinct patterns of sleep inertia were established: persistent-low group, alleviating group, deteriorating group, and persistent-high group. The persistent-low group, characterized by SIQ total scores below the cut-off value of 69 at both T1 and T2, comprised 717 (66.5%) participants. The alleviating group (n = 89, 8.2%) was characterized by SIQ scores being equal or above the cut-off value at T1 but below at T2; while the deteriorating group (n = 142, 13.2%) was characterized by SIQ scores being below the cut-off value at T1 but equal or above at T2. Additionally, the persistent-high group comprised 131 participants (12.1%) who had SIQ scores equal or above the cut-off value at two waves. More detailed information on the four patterns of sleep inertia is shown in Table 1.

### Temporal Networks Across Four Distinct Change Patterns of Sleep Inertia Network Structure

The CLPN network structures of four distinct change patterns of sleep inertia are depicted in Figure 2. Overall, the persistent-low group exhibited the highest number of estimated edges (n = 181), followed by the persistent-high (n = 94), alleviating (n = 62), and deteriorating (n = 40) groups. As shown in Table 2, all estimated edges and autoregressive edges



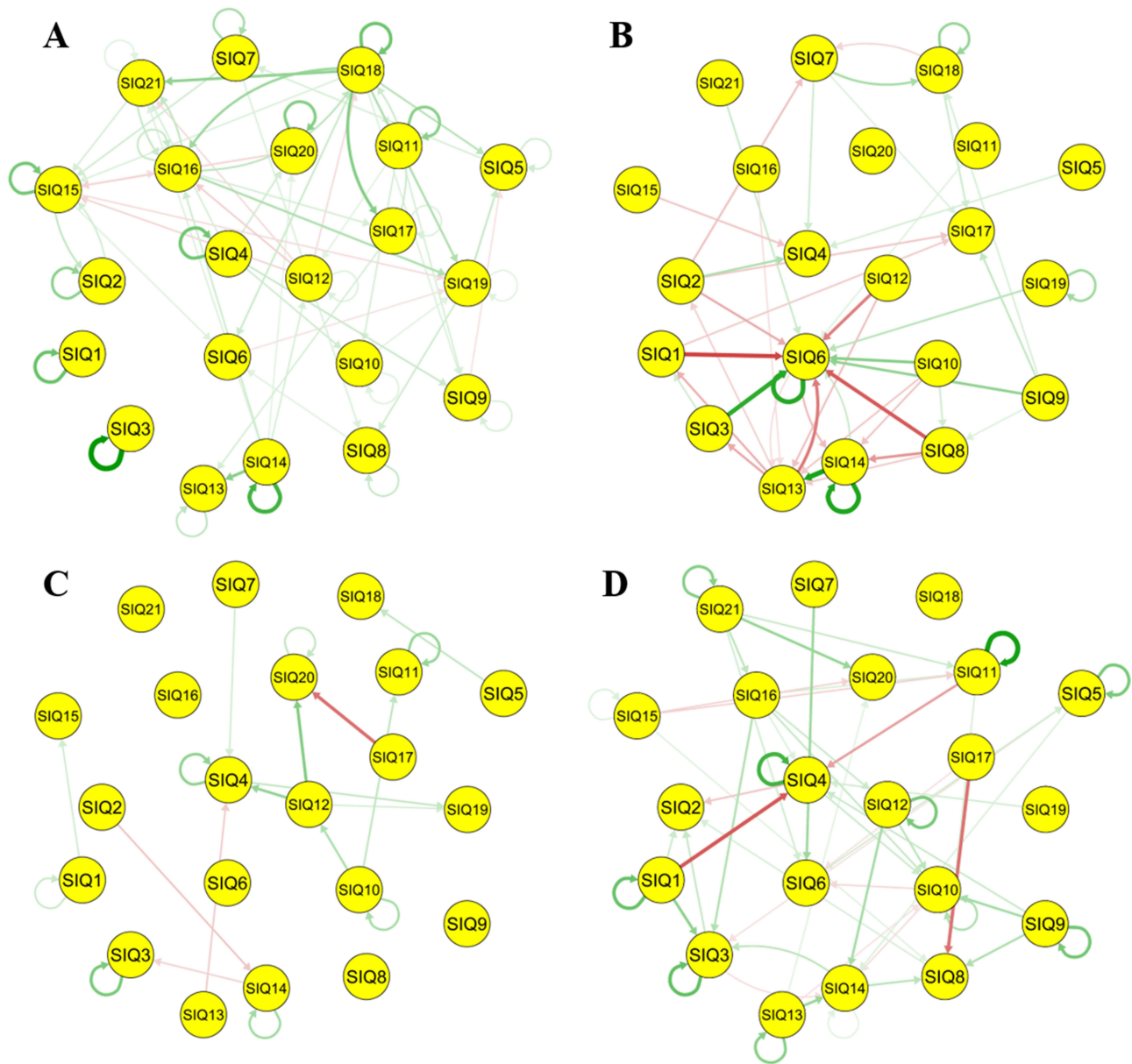
**Figure 1** The four SI's trajectories from half a month to three and half months after their clinical internship among 1079 intern nurses. **Abbreviations:** SI, sleep inertia; T1, Time 1; T2, time 2.

**Table 1** Differences on Demographic and Sleep-Related Factors Between the Four Change Patterns of Sleep Inertia

Variable	n	%	Persistent-Low Group (n = 717)	Alleviative Group (n = 89)	Deteriorated Group (n = 142)	Persistent-High Group (n = 131)	$\chi^2$	$\eta^2$
<b>Sex<sup>a</sup></b>							0.433	0.013
	60	5.6	42	4	7	7		
	1019	94.4	675	85	135	124		
<b>Morningness-eveningness type<sup>b</sup></b>							101.812***	0.292
	99	9.2	85	8	5	1		
	702	65.1	509	44	86	63		
	278	25.8	123	37	51	67		
<b>Flexibility of the rhythm<sup>b</sup></b>							17.567**	0.102
	238	22.1	153	19	27	39		
	593	55.0	379	49	94	71		
	248	23.0	185	21	21	21		
<b>Ability to overcome drowsy<sup>b</sup></b>							213.291***	0.436
	230	21.3	201	13	8	8		
	582	53.9	420	55	68	39		
	267	24.7	96	21	66	84		
<b>Subjective sleep quality<sup>a</sup></b>							105.677***	0.271
	498	46.2	389	22	59	28		
	501	46.4	305	50	68	78		
	80	7.4	23	17	15	25		
<b>Sleep duration<sup>a</sup></b>							66.732***	0.224
	47	4.4	33	4	7	3		
	707	65.5	520	44	86	57		
	325	30.1	164	41	49	71		

**Notes:** <sup>a</sup>Variables were assessed at T1; <sup>b</sup>Variables were assessed at T2. \*\*p < 0.01, \*\*\*p < 0.001.

showed no significant differences among four networks, while the cross-lagged edges were significantly different ( $F = 3.121$ ,  $p < 0.05$ ,  $\eta^2 = 0.028$ ). Furthermore, we applied the Bonferroni correction to adjust the significance levels for multiple comparisons. The results found a significant difference in the cross-lagged edges between the persistent-low and alleviating groups (Difference of mean = 0.03,  $p < 0.05$ ). Notably, the strongest cross-lagged edges were observed: “React more slowly (SIQ18) - Think more slowly (SIQ17)” in the persistent-low group (edge-weighted value = 0.20), “Dread starting your day (SIQ14) - Anxious about the upcoming day (SIQ13)” in the alleviating group (edge-weighted value = 0.38), “Feeling tense (SIQ12) - Resist to wake up (SIQ20)” in the deteriorating group (edge-weighted value = 0.20), and “Difficulty in getting up (SIQ1) - Hit the snooze button on the alarm (SIQ3)” in the persistent-high group (edge-weighted value = 0.19). More detailed information for edge-weighted values can be found in [Supplementary Tables 1–4](#).



**Figure 2** Cross-lagged panel networks across four distinct SI's trajectories. A threshold of all edge weights was manually set to 0.05 to make the figures more interpretable. **Notes:** Each curved arrow “loop” reflects an autoregressive association; White nodes indicate depressive symptoms; Blue lines indicate positive relations, whereas red lines signal negative relations, and line thickness and boldness reflect the strength of associations. **(A)** Persistent-low group; **(B)** Alleviative group; **(C)** Deteriorated group; **(D)** Persistent-high group; SIQ, Sleep Inertia Questionnaire; SIQ1, Difficulty in getting up; SIQ2, Need an alarm to wake up; SIQ3, Hit the snooze button on the alarm; SIQ4, Bump into and drop things; SIQ5, Move more slowly; SIQ6, Feel sleepy; SIQ7, Heavy, sore, or itchy eyes; SIQ8, Tired or heavy arms and/or legs; SIQ9, Groggy, fuzzy or hazy mind; SIQ10, Get winded more easily; SIQ11, Difficulty in keeping balance; SIQ12, Feel tense; SIQ13, Anxious about the upcoming day; SIQ14, Dread starting your day; SIQ15, Wish to sleep more; SIQ16, Difficulty in concentrating; SIQ17, Think more slowly; SIQ18, React more slowly; SIQ19, Make more mistakes/errors; SIQ20, Resist to wake up; SIQ21, Difficulty in getting your thoughts together.

## Network Inference

More specifically, symptoms with the high out-EI in the persistent-high group included “Difficulty in concentrating” (SIQ16; out-EI = 1.80), “Difficulty in getting your thoughts together” (SIQ21; out-EI = 1.71), and “Groggy fuzzy or hazy mind” (SIQ9; out-EI = 1.34); while symptoms in the deteriorating groups were “Feeling tense” (SIQ12; out-EI = 3.02) and “Get winded more easily” (SIQ10; out-EI = 1.49). **Figure 3** shows further details regarding the standardized values of in-EI and out-EI. **Table 3** provides the results of multiple comparisons using the Bonferroni correction between in EI and out EI.

**Table 2** Comparison on Edge Weights and Centrality Indicators in Four Networks of Distinct Change Patterns of Sleep Inertia

	Persistent-Low Group (n = 717)		Alleviative Group (n = 89)		Deteriorated Group (n = 142)		Persistent-High Group (n = 131)		F	$\eta^2$
	M±SD	N	M±SD	N	M±SD	N	M±SD	N		
<b>Edge weights</b>										
All estimated edges	0.04±0.07	181	0.01±0.14	62	0.04±0.09	40	0.05±0.10	94	2.503	0.02
All autoregressive edges	0.15±0.10	21	0.26±0.12	4	0.15±0.04	7	0.20±0.10	13	1.929	0.124
All cross-lagged edges	0.03±0.05	160	-0.01±0.13	58	0.02±0.08	33	0.03±0.08	81	3.121*	0.028
<b>Centrality indicators</b>										
In-EI	0.20±0.11		0.02±0.12		0.03±0.08		0.11±0.13		15.973***	0.375
Out-EI	0.20±0.30		0.02±0.30		0.03±0.14		0.11±0.20		3.382*	0.113

Note: \*p < 0.05, \*\*\*p < 0.001.

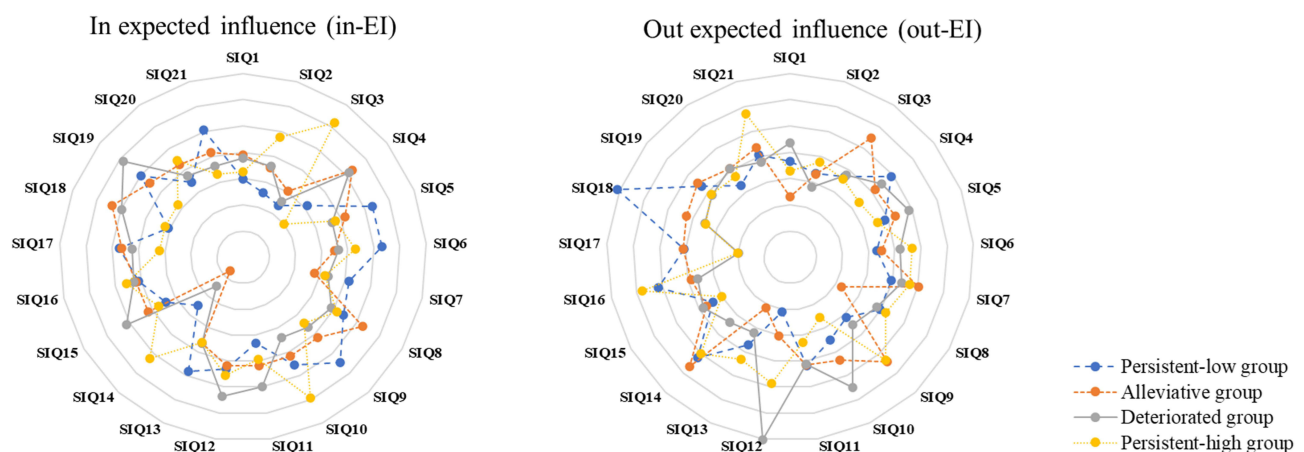
Abbreviations: M, mean; SD, standard deviation; in-EI, in expected influence; out-EI, out expected influence.

### Network Stability and Accuracy

The bootstrapped 95% CIs tests indicated that 95% CIs of all edges were small to moderate (Supplementary Figure 1). Statistical significance was observed in the results of the bootstrap difference test for edges and centrality indicators Supplementary Figures 2–4 Stability analyses for in-EI and out-EI centrality suggested partial stability (Supplementary Figure 5). Specifically, in-EI centrality is 0.51 in the persistent-low group, 0.11 in the alleviating group, 0.11 in the deteriorating group, and 0.05 in the persistent-high group, and out-EI centrality is 0.34 in the persistent-low group, 0.07 in the alleviating group, 0.18 in the deteriorating group, and 0.15 in the persistent-high group.

## Discussion

To the best of our knowledge, this study is the first to uncover temporal networks of sleep inertia across its distinct change patterns using longitudinal data. We have two main findings in this study. On the one hand, we established four distinct patterns of sleep inertia. On the other hand, we found differences in those symptoms with the highest influence on other symptoms at the subsequent point across the networks of four change patterns. Particularly, “Difficulty in



**Figure 3** Centrality estimates of in-EI (Left) and out-EI (Right) using z values between four distinct SI's trajectories.

Notes: Higher values indicate more centrality. SIQ, Sleep Inertia Questionnaire; SIQ1, Difficulty in getting up; SIQ2, Need an alarm to wake up; SIQ3, Hit the snooze button on the alarm; SIQ4, Bump into and drop things; SIQ5, Move more slowly; SIQ6, Feel sleepy; SIQ7, Heavy, sore, or itchy eyes; SIQ8, Tired or heavy arms and/or legs; SIQ9, Groggy, fuzzy or hazy mind; SIQ10, Get winded more easily; SIQ11, Difficulty in keeping balance; SIQ12, Feel tense; SIQ13, Anxious about the upcoming day; SIQ14, Dread starting your day; SIQ15, Wish to sleep more; SIQ16, Difficulty in concentrating; SIQ17, Think more slowly; SIQ18, React more slowly; SIQ19, Make more mistakes/errors; SIQ20, Resist to wake up; SIQ21, Difficulty in getting your thoughts together.

**Table 3** The Results of Multiple Comparisons Using the Bonferroni Correction Between in EI and Out EI

	Group (I)	Group (J)	Mean(I) - Mean(J)	p	95% CI	
In-EI	Persistent-low	Alleviative	0.22*	<0.001	[0.13, 0.32]	
		Deteriorated	0.17*	<0.001	[0.08, 0.27]	
		Persistent-high	0.10*	0.042	[0.00, 0.19]	
	Alleviative	Persistent-low	-0.22*	<0.001	[-0.32, -0.13]	
		Deteriorated	-0.05	0.940	[-0.14, 0.04]	
		Persistent-high	-0.13*	0.002	[-0.22, -0.03]	
	Deteriorated	Persistent-low	-0.17*	<0.001	[-0.27, -0.08]	
		Alleviative	0.05	0.940	[-0.04, 0.14]	
		Persistent-high	-0.08	0.153	[-0.17, 0.01]	
	Persistent-high	Persistent-low	-0.10*	0.042	[-0.19, 0.00]	
		Alleviative	0.13*	0.002	[0.03, 0.22]	
		Deteriorated	0.08	0.153	[-0.01, 0.17]	
Out-EI		Persistent-low	Alleviative	0.22*	0.023	[0.02, 0.43]
		Deteriorated	0.17	0.137	[-0.03, 0.38]	
		Persistent-high	0.10	1.000	[-0.11, 0.30]	
Alleviative	Persistent-low	-0.22*	0.023	[-0.43, -0.02]		
	Deteriorated	-0.05	1.000	[-0.25, 0.15]		
	Persistent-high	-0.13	0.555	[-0.33, 0.08]		
Deteriorated	Persistent-low	-0.17	0.137	[-0.38, 0.03]		
	Alleviative	0.05	1.000	[-0.15, 0.25]		
	Persistent-high	-0.08	1.000	[-0.28, 0.12]		
Persistent-high	Persistent-low	-0.10	1.000	[-0.30, 0.11]		
	Alleviative	0.13	0.555	[-0.08, 0.33]		
	Deteriorated	0.08	1.000	[-0.12, 0.28]		

Note: \*p < 0.05.

Abbreviation: 95% CI, 95% confidence interval.

concentrating” in the persistent-high group and “Feeling tense” in the deteriorating groups should be prioritized for attention in interventions targeting sleep inertia.

In the current study, we established four change patterns for long-term sleep inertia among intern nurses with shift work: persistent-low (66.5%), alleviating (8.2%), deteriorating (13.2%), and persistent-high (12.1%) groups. This finding is partially consistent with our prior investigation,<sup>21</sup> indicating distinct latent profiles of sleep inertia among Chinese college students. Additionally, according to previous research regarding change patterns in sleep-related problems,<sup>28,29,36</sup> we could postulate that sleep inertia has large individual differences in people’s responses and adaptation processes to shift work. Several plausible explanations can elucidate this finding. First, sleep inertia, as the third process of sleep regulation, reflects the interplay between a homeostatic drive or pressure for sleep and a circadian rhythm of arousal.<sup>37</sup> Given that shift work has a profound impact on the pressure for sleep over time,<sup>38</sup> sleep inertia might consequently display a different pattern in the



long-term period. Second, people perceive the world differently, leading to individual differences in vulnerability to sleep inertia.<sup>39</sup> Further studies are needed to validate the specific explanations mentioned above.

Our findings suggest that central symptoms with the highest out-EI values vary across the four heterogeneous networks of sleep inertia. Due to the lack of network analysis results for sleep inertia subgroups, there is no reference basis for the current findings. However, previous network analysis studies on subgroups of depression or posttraumatic stress symptoms have shown that the key symptoms across subgroups are different.<sup>20,32,33</sup> These studies can partially support the current finding. Taken together, sleep inertia exhibits significant individual differences, highlighting the importance of future research to further explore its long-term heterogeneity.

Evidence has suggested that symptoms with the highest out-EI play a role in the onset or development of psychological symptoms.<sup>15,40</sup> Given the availability and effectiveness of clinical interventions,<sup>15,29,40</sup> priority should be given to focusing on those symptoms with the highest out-EI in the deteriorating and persistent-high groups. More specifically, our study reveals firstly that “Difficulty in concentrating” exhibited the greatest influence on other symptoms within the network with the persistent-high sleep inertia among intern nurses with shift work. Several experimental studies provide partial support for significant impairment of vigilance due to sleep inertia.<sup>41–44</sup> For example, Santhi et al found that alertness was most strongly affected by sleep inertia followed by other cognitive functions.<sup>44</sup> Notably, shift work involves exposure to light and eating during the biological night while sleeping during the biological day, causing misalignment with the endogenous circadian system,<sup>45</sup> which may contribute to persistent-high sleep inertia. Alertness has emerged as a fundamental and crucial component of human performance in many work environments.<sup>46</sup> Consequently, the aforementioned evidence helps explain why “Difficulty in concentrating” could strongly predict other symptoms three and a half months after the clinical internship among intern nurses with shift work. A recent study indicated that mindfulness-based interventions can help individuals feel less stressed improve their ability to concentrate.<sup>47</sup> Therefore, these interventions should be employed to enhance concentration in individuals experiencing persistent high sleep inertia.

Furthermore, “Feeling tense” exhibited the most significant influence on other symptoms within the network characterized by deteriorating sleep inertia. Similar to our previous published study,<sup>48</sup> “Dread starting your day” emerged as a central symptom within the cross-sectional network of sleep inertia among Chinese college students. These findings indicate that negative effects such as irritability and anxiety tend to manifest during the sleep-wake transitional state sleep inertia.<sup>25,48,49</sup> It is noteworthy that the desire to return to sleep is one of the characteristics of sleep inertia,<sup>3</sup> potentially indicating that individuals with more severe sleep inertia might endure insufficient sleep. Sleep loss is closely associated with worsened mood and decreased ability to regulate negative emotions, even exhibiting somatic symptoms.<sup>50</sup> Further, nurses with shift work report frequently poorer sleep quality and reduced sleep duration, which could impact an individual’s positive effects.<sup>45</sup> Therefore, we thought that “Feeling tense” may activate and maintain other symptoms within the network with the deteriorating sleep inertia among intern nurses with shift work. According previous studies,<sup>47,51</sup> techniques such as deep breathing exercises, progressive muscle relaxation, and mindfulness meditation have been shown to reduce anxiety and tension. Therefore, these techniques can be beneficial for individuals experiencing worsening sleep inertia.

Notably, this study made a unique contribution to the underlying mechanisms of sleep inertia at the symptom level across distinct change patterns over time. However, it is crucial to acknowledge several limitations. First, the sample only consisted of intern nurses with shift work, potentially limiting the generalizability of findings to other populations such as firefighters, police officers, or pilots due to sex, workplace stability, anticipating a stressful task, frequency of on call.<sup>8,52</sup> Second, the reliance on subjective self-reports of sleep inertia may introduce potential biases into our findings. Therefore, future studies need reliable and objective measures (eg, psychomotor vigilance task) to measure sleep inertia. The emergency services sectors can prioritize The possible reason is that the temporal nature of symptoms remains unresolved, which is a crucial consideration when selecting a sampling scheme for within-subject studies<sup>14</sup> (ie, How many time points per day or week should be planned?). Fourth, we considered only a limited range of variables and omitted other important information, such as details about the clinical internship and the participants’ shift work schedules (ie, nights per week, rotation direction/speed, days off, or work days). Fifth, similar to previous studies,<sup>53–55</sup> categorizing individuals into groups based on whether they have a disease or not will inevitably lead to an imbalance in the number of people in each group. Finally, due

to the low stability and accuracy of the estimated network for the three small sample groups, the results should be interpreted with caution. Future research should prioritize expanding the sample size to validate these results.

## Conclusions

The current study highlights changes in sleep inertia based on the long-term course over time. Notably, symptoms of “Difficulty in concentrating” in the persistent-high group and “Feeling tense” in the deteriorating groups were most predictive of other symptoms at follow-up. Taken together, it is imperative to address these specific symptoms within subpopulations.

## Data Sharing Statement

The data that support the findings in the current study are available from the corresponding author upon reasonable request.

## Ethics Approval

Our study was approved by the Human Research Ethics Committees of SCNU and carried out in line with the Helsinki Declaration as revised in 1989.

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## Disclosure

The authors report no other conflicts of interest in this work.

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