Sleep EEG characteristics associated with total sleep time misperception in young adults

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Backgroud: Power spectral analysis (PSA) is one of the most commonly-used EEG markers of cortical hyperarousal which help to understand subjective-objective sleep discrepancy (SOD). Age is associated with decreased sleep EEG activity. Currently, PSA of young adults are limited. Thus, this study aimed to examine the correlation of spectral EEG power with total sleep time misperception in young patients.

Methods: Forty-seven young adults were recruited and underwent a polysomnography recording in a sleep laboratory. The clinical records and self-report questionnaires of all patients were collected, who were categorized into the GS (n=10), insomnias with a low mismatch (IWLM, n=19) and participants with a high mismatch (IWHM, n=18) subgroups. Power spectral analysis was performed during the first 6 hours of sleep.

Results: The IWLM group showed increased absolute beta power in central-frontal area and relative beta power in frontal areas compared to the GS group. In addition, IWHM patients exhibited higher absolute and relative beta power in the central area compared to the GS group. The absolute and relative beta/delta ratios in frontal area in the IWHM and IWLM groups were higher than those in the GS group. The IWHM group also showed higher absolute and relative beta/delta ratios in the central area compared with the GS group. No significant difference in the above parameters was observed between the IWHM and IWLM groups. Moreover, the SOD of TST was negatively correlated with the relative delta power ($r=0.289$, $p=0.049$), beta power ($r=0.373$, $p=0.010$), beta/delta ratio($r= 0.314$, $p=0.032$), and the absolute beta/delta ratio ($r=0.314$, $p=0.032$) in central area.

Conclusions: Young IWHM and IWLM patients showed increased beta EEG power compared to GS, suggesting that there exists increased cortical activity in these patients. Also, the beta/delta ratio was negatively correlated with the SOD in patients with IWHM and IWLM.

Keywords: young adult; misperception; EEG; power spectral analysis; cortical activation

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1.1 Introduction

Insomnia is a common disease in modern society with a prevalence rate ranging from 12-20%[1]. Patients with insomnia have an increased risk of developing mental illness[2] and physical diseases[3, 4], which is often accompanied by increased healthcare and medical costs, higher absenteeism, higher incidence of traffic accidents and falls, and a reduced quality of life[4-7].

Subjective-objective sleep discrepancy (SOD) refers to the underestimation of total sleep time (TST) and overestimation of sleep onset latency (SOL), and is very ubiquitous in insomnia patients[8,9]. It could reach an extreme degree in Paradoxical insomnia (Par-I), which was used to be named in the International Classification of Sleep Disorders - 2rd Edition (ICSD-2) , but cancelled in ICSD -3 mainly due to lack of agreement on its precise definition. Although the disease name has been cancelled, the phenomenon it represents is common in insomnia patients. It is worth to study[10], and is an important aspect to understand insomnia.

Several researches have been studied to explain the SOD in insomnias referring thirteen possible mechanisms supported by good-quality evidence[8].One of them is about cortical hyperarousal. Power spectral analysis (PSA) is one of the most commonly-used EEG markers of cortical hyperarousal[11] and it represents enhanced sensory information processing, which can lead to sleep state misperception[12]. The power of each waveform is defined as the area below the waveform with the greater the amplitude indicating greater power[8].

Previous studies have shown that high-frequency EEG activity, especially beta activity, is increased in patients with primary insomnia (PI) at sleep onset, during non-rapid eye movement (NREM) sleep[13-16], and even during wakefulness[17,18]. This divergence may be explained by one of the fact that the types of insomnia are not considered in most studies, for example[8], individuals with and without misperception. Krystal *et al.*[19] , St-Jean *et al.*[20]and Sandro Lecci *et al.* [21] categorized their patients according to different types of insomnia. However, there was no consistency in the spectral power and only elderly patients (40-80 years old vs. 40.21+9.38 vs 40 - 85 years old) were included in these studies. It has also been shown that age is associated with decreased sleep EEG activity[22, 23]. Less slow-wave and spindle activity during non-rapid eye movement (NREM) sleep, together with attenuated levels of rapid eye movement (REM) sleep are exhibited in older people than that in young individuals[24]. In this study, we aimed to compare the TST in young patients who overestimated their sleep by at least two hours, relative to a group who correctly estimated their sleep, and good sleepers (GS). Our findings may be important for clinical and public health and for the treatment and management of insomnia[8].

2.1 Materials and Methods

Participants

Seventy participants aged between 18 to 40 years were recruited from the Guangdong Provincial Hospital of Chinese Medicine through posters from May 2016 to November 2017. All subjects were asked to complete a two-week sleep diary followed by a single all-night PSG recording in a sleep monitoring room. Personal information was obtained from all subjects and included age, sex, race, place of residence, marital status, family history of insomnia, and family history of psychosis. Two self-reported

questionnaires, the Pittsburgh Sleep Quality Index (PSQI)[25] and the Symptom Checklist 90 (SCL-90), were given to each participant. Subjective sleep quality was determined by self-reported TST after PSG. The following questions were asked to the subjects within two hours after completion of polysomnography using standardized questions: “How long did you sleep last night?” and “Did you sleep as usual?”

Subjects were eligible to be enrolled as GS if they 1) reported no difficulty in sleep according to the two-week sleep diary (i.e. a SOL of < 30 min, awakenings of < 40 min, a TST between 6.0 to 8.0h, or a sleep efficiency (SE) of ≥ 85%); 2) had a PSQI score of < 7[25]. Participants with a SE of < 85% or sleep time of < 6 h were excluded from this study.

Participants were defined as insomnia patients if they 1) met the diagnostic criteria for chronic insomnia disorder (International Classification of Sleep Disorders, 3rd edition); 2) reported at least three nights per week of sleep difficulty (i.e. a SOL of > 30 min, awakenings of > 40 min, a TST of < 6.0 h, or a SE of < 85%); 3) had a PSQI score of >7; 4) had difficulty sleeping for more than three months; 5) did not have other medical, psychological, or sleep disorders or take other medications.

Insomnia patients were further categorized into the insomnias with a low mismatch (IWLM) and participants with a high mismatch (IWHM) subgroups. IWLM were defined as individuals who met the criteria for chronic insomnia disorder and had a SOD of < 60 min in TST. IWHM were defined as those who met criteria for chronic insomnia disorder and had normal PSG parameters (i.e. an SE of> 85% and a TST of> 6.5 h) and a SOD of > 120min in TST. In both the IWHM and IWLM groups, patients

were excluded if they 1) were diagnosed with another Axis I disorder or any other sleep disorders(e.g. idiopathic insomnia, sleep apnea, which was defined as an apnea-hypopnea index of more than five events per hour using PSG, or restless leg syndrome); 2) were affected by other external factors that might affect insomnia (e.g., physical pain caused by medical diseases, drugs affecting sleep structure, alcohol consumption, other treatments, etc.); 3) went to sleep later than 0:00am or woke up before 6:00 am, or had irregular sleep schedules.

Based on the inclusion and exclusion criteria, 47 participants were included in the study: GS group (n=10; 5 males,5 females), IWLM group (n=19; 3 males, 16 females), and IWHM group (n=18; 9 males,9 females).

PSQI and SCL-90

The PSQI is a questionnaire consisting of 21 items and has been commonly used to evaluate subjective sleep quality. The higher the score, the greater the severity of insomnia. A score of >7 indicates abnormal sleep (severe difficulty in at least two areas or moderate difficulty in more than three areas).

The SCL-90 is one of the most widely used mental health scales in the field of psychiatry. It is a 90-item, self-reported symptom inventory. The score for each item is summed, yielding a total score that covers ten aspects. The higher the total score, the greater the risk of developing psychological distress[27].

PSG Recordings

In conventional PSG (Nicolet, ONE, EEG 32, USA), the international 10-20 system is used to record EEG. In the current work, the grounding electrode was placed on the frontal pole midline point and the bilateral ear electrodes were used as the reference. An electrographic electrode was placed near each eye to track eye movement. The impedance was kept below 5kΩ for all electrodes. The surface electrodes included four EEG (two central electrodes (C3, C4), two frontal EEG electrodes (F3, F4)), two electrooculogram (EOG), submental electromyogram (EMG), electrocardiogram (ECG), and two reference electrodes (M1, M2). In addition, tibialis EMG and respiration were monitored to exclude artifacts due to periodic limb movements (a myoclonus arousal index of >15) and sleep apnea (an apnea-hypopnea index of > 5). Participants were asked to sleep at their usual time (before 0:00am) and wake up at 7:00 am. The sampling rate for EEG acquisition was 500 Hz and the filter settings were as follows: notch frequency60 Hz; low pass filter 35 Hz; high pass filter 0.3 Hz.

Sleep records were reviewed and scored by a registered polysomnography technician according to the revised AASM 2.5 sleep scoring criteria[28]. The sleep continuity parameters, including TST, SPT, SE (ratio of TST to time in bed ×100), and SOL, and sleep architecture parameters, including the number of awakenings, the number of arousals, arousal index, percentage of stages 1 and 2, slow wave sleep (SWS), and rapid eye movement (REM) sleep of TST were analyzed.

Spectral Analysis

The time-domain data from the first 6-h of sleep from a central and frontal EEG electrode (averaged C3-A2 and C4-A1 channels, averaged F3-A2 and F4-A1 channels) were transformed into the frequency-domain using the fast Fourier transforms (FFT). EMG artifacts were automatically detected and rejected from all analysis[29]. EEG was amplified with a solution of 0.25 Hz, an EEG segment length of 6 h, a bandpass filter setting of 0.5–30Hz (−3dB), and a frequency of 200Hz.

The beta (13–30 Hz), alpha(8–13 Hz), delta (0.5–4 Hz), and theta (4–8 Hz) band activity were extracted for PSA analysis. The values of relative spectral power were calculated by dividing the absolute power of each frequency band by the power of the total power spectrum. The values of the absolute and relative spectral power of the NREM sleep were log-transformed before data analysis.

Statistical Analysis

Statistical analysis was performed by the SPSS software (ver. 24.0) using unpaired two-tailed tests of significance. One-way ANOVAs or non-parametric analysis with post-hoc analysis was used to evaluate statistical significance between groups and family-wise error rate due to multiple comparisons was controlled using Bonferroni's correction (corrected α=0.002). Levene's test and the Normal test were performed before an ANOVA to examine the homogeneity and distribution of the variance. Pearson's correlation analysis was used to determine the correlation between EEG spectral power (absolute and relative) and the SOD of TST. $P<0.05$ was considered statistically significant.

3.1 Results

3.1.1 Baseline characteristics

There was no significant difference in age, sex, race, place of residence, marital status, family history of insomnia, or family history of psychosis among the three groups (Table 1).

3.1.2 PSQI, SCL90, and PSG characteristics

The comparisons of the PSQI score, SCL-90 score, and PSG among the three groups are shown in Table 2. The IWHM and IWLM groups showed higher PSQI and SCL-90scores compared to the GS group. However, there was no significant difference in the PSQI or SCL-90 scores between the IWHM and IWLM groups. The PSG parameters were not significantly different among the GS, IWHM, and IWLM groups.

3.1.3 Absolute EEG spectral power

Post-hoc analysis (Kruskal-Wallis test) revealed that the IWLM group exhibited significantly higher beta power in the frontal area than the GS group. Also, the beta power in the central area was significantly higher in the IWHM and IWLM groups compared to the GS group. The IWHM and IWLM groups exhibited a significantly higher beta/delta ratio in the frontal area than the GS group. A significantly higher beta/delta ratio in the central area was also observed in the IWHM group compared tothe GS group. There was no significant difference in these parameters between the IWHM and IWLM groups (Table 3).

3.1.4 Relative EEG spectral power

The average NREM activity for beta activity and the beta/delta ratio in the central or frontal area were significantly different among groups. Post-hoc analysis (Kruskal-Wallis test) showed that the frontal beta power in the IWLM group was higher than that in the GS group. Also, the IWHM group had a significantly higher beta power in the central area compared to the GS group. A significantly higher beta/delta ratio in the frontal area was found in the IWHM and IWLM groups compared with the GS group. The IWHM group also had a significantly higher beta/delta ratio in the central area than the GS group. No significant difference in relative spectral power was observed between the IWHM and IWLM groups (Table 4).

3.1.5 Correlation between absolute EEG spectral power and SOD

The absolute EEG spectral power and beta/delta ratio in the central area were positively and significantly correlated with the SOD of TST (r=0.314, p=0.032)(Table 5).

3.1.6 Correlation between relative EEG spectral power and SOD

The relative delta (r=0.289, p=0.049) and beta (r=0.373, p=0.010) power, as well as the beta/delta ratio (r=0.314, p=0.032) in the central area were significantly correlated with the SOD of TST (r=0.314, p=0.032) (Table 6).

4.1 Discussion

This is the first study, to the best our knowledge, that has investigated the absolute and relative spectral power of young adult patients (18-40years old) with insomnia. Here, we categorized insomnia patients into the IWLM and IWHM groups to

maximize the difference in the SOD. Compared to the GS group, patients with IWLM and IWHM exhibited an increase in the absolute and relative beta (13–30 Hz) frequencies and the beta/delta ratio in the central-frontal area during sleep. Moreover, the SOD of TST was positively correlated with the absolute and relative beta/delta ratio in the central area in insomnia patients. However, no significant difference was observed in the EEG power or beta/delta ratio in the central area between the IWLM and IWHM groups. Also, there was no significant difference in the absolute and relative beta power in the frontal area between the IWHM and GS groups.

Beta power is generally thought to be an index of cortical arousal. It has been shown that beta activity in the PI-group is higher than that in GS[13-16]. Here, we found that the IWHM group exhibited a significantly increased absolute and relative beta power in the central region, indicating increased cortical arousal during sleep. These results suggest that the IWHM group may experience enhanced sensory processing during sleep, which may render them highly responsive and sensitive to external sounds. This in turn may also lead to the mistaken perception of their sleep as wakefulness[12]. Our findings are similar to a previous EEG-based spectral investigation by Krystal *et al.* [19] that showed greater beta NREM EEG activity in IWHM patients relative to GS. Nevertheless, unlike this previous work, we did not observe lower delta NREM EEG activity, or greater alpha, sigma (11–14 Hz), or beta NREM EEG activity in the IWHM group. This discrepancy may be attributed to the differences in the age and diagnostic criteria of IWHM patients between the two studies.

In our study, the IWLM group revealed increased absolute and relative beta power in the frontal area and increased absolute beta power in the central area compared to

GS. These results are again inconsistent with the results reported by Krystal *et al.*[19] and St-Jean *et al.*[20] that showed no difference between IWLM and GS participants. One possible explanation is that patients of different ages were selected in the various studies and that different sleep stages were analyzed.

Recently, the ratio of high-frequency to low-frequency EEG power has been recognized as a novel indicator of cortical arousal. Furthermore, individuals with a higher ratio of this sort may have more sleep difficulties. Meric *et al.*[30] found that IWLM patients exhibited an increased beta/delta ratio in the temporal lobe during the sleep onset period (SOP). However, some studies have also reported that delta EEG activity is decreased in IWLM patients in the temporal and central brain areas during the SOP[18,31]. Thus, such an activity index (beta/delta ratio) may be a more appropriate indicator of cortical arousal in insomnia patients [16, 30,32].In the current study, both the IWHM and IWLM groups showed increased absolute and relative beta/delta ratio in the central area when compared with the GS group.

We further showed that the SOD of TST in insomnia patients was moderately associated with the absolute NREM beta/delta ratio (r=−.314), relative beta power (r=−.373), and relative beta/delta ratio (r=−.314), and slightly associated with the relative delta spectral power (r=−.289) in the central area. Overall, these results indicate that the higher the beta/delta ratio and beta power during NREM sleep, the greater underestimation of TST. Our results are similar to the findings by Perlis *et al*[13]. which showed a moderate correlation between the SOD of TST and NREM beta activity (14–35Hz) (r=−.46). The underestimation of TST may be explained by the insertion of high frequency EEG into low frequency EEG, which has been shown to enhance information processing and reduce sleep quality[33].

There are various limitations to our study that must be noted. First, only one PSG recording was performed in each participant and thus, the results might be biased by the “first night” effect. Secondly, insomnia patients were categorized into the IWHM and IWLM groups based only on TST and the percentage of SWS should also be considered in future investigations. Lastly, the sample size in this work was relatively small. Future studies with larger sample sizes are needed to further elucidate the neurophysiological mechanisms about the SOD.

5.1 Conclusion

In conclusion, the present study suggests that insomnia in young adults is associated with increased absolute beta EEG power in the central brain area. Compared to healthy subjects, IWHM patients exhibited increased relative beta power in the central area and IWLM patients exhibited higher beta power in the frontal area, indicating that that cortical hyper arousal was present in all insomnia patients. Hyperarousal (e.g., beta EEG power) in the frontal area was only observed in patients with IWLM. Moreover, the SOD of TST was associated with beta/delta ratio, indicating sleep disruption in insomnia patients.

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Author contributions

Biyun Xu: data analysis and interpretation, manuscript drafting/revision. Qinghao Cai: major role in data acquisition. Runru Ma: manuscript revision. Hailong Liang: study supervision, critical revision of the manuscript. Jiayu Huang: data collection,

manuscript revision. Zhimin Yang: study concept and design, critical revision of the manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on request.

Ethics approval and consent to participate

This clinical trial was approved by the Ethics Committee of the Guangdong Provincial Hospital of Chinese Medicine (number: B3016-075) and performed in accordance with the World Medical Association Declaration of Helsinki. This study was registered on http://www.chictr.org/up (registration number: chiCTR-COC-16008530). Informed consent was obtained from all subjects prior to participation.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Table 1 Demographic characteristics of all participants

Variable	GS (n = 10)	IWHM (n = 18)	IWLM (n = 19)	Statistics
Age, years	26.90±2.89	31.39±6.11	28.95±7.04	χ^2=3.378, *p*= 0.185
Sex（F/M）	5/5	9/9	16/3	χ^2=5.616, *p*= 0.060
Race				χ^2=0.000, *p*= 1.000
Han	10	18	19	
Non-Han	0	0	0	
Place of residence				χ^2=1.233, *p*= 0.540
Downtown	9	13	15	
Suburb	1	4	3	
Village	0	1	1	
Marriage				χ^2=2.798, *p*= 0.247
Unmarried	7	7	10	
Married	3	10	9	
Bereavement/ divorce	0	1	0	
Family history of insomnia （Y/N）	1/9	3/15	1/18	χ^2=1.243, *p*= 0.537
Family history of psychosis （Y/N）	0/10	0/18	1/18	χ^2=1.474, *p*= 0.479

Data are mean ± standard deviation (SD) or n (%) values.

GS, good sleeper; IWLM, insomnias with a low mismatch; IWHM, insomnias with a high mismatch

Table 2- PSQI scores, SCL90scores,and PSGcharacteristics of all participants.

Variable	GS (n = 10)	IWHM (n = 18)	IWLM (n = 19)	Statistics
PSQI total score	3.80±2.39	13.17±3.65[a]	11.29+4.44 [a]	χ^2=18.882, *p*= 0.000
SCL-90 total score	115.90±16.63	185.44±51.41 [a]	155.00±39.57 [a]	χ^2=16.037, *p*= 0.000
TST (min)	394.25±45.25	415.06±40.20	381.95±39.85	F =3.026, *p*= 0.059
SPT(min)	418.60±47.39	459.03±42.65	431.84±49.77	F =2.837 *p*= 0.069
SE, %	89.27±3.92	87.84±7.00	86.24±8.39	F =0.626, *p*= 0.540
SOL (min)	13.75±9.01	10.58+10.37	8.24±6.84	χ^2=2.697, *p*= 0.260
%NREM stage1	4.70±1.70	6.00±3.03	5.42±2.83	χ^2=1.158, *p*= 0.560
%NREM stage2	59.40±8.51	61.17±8.61	62.16±7.63	F =0.371, *p*= 0.692
% SWS	13.60±4.79	10.06±6.49	12.37±4.82	F =1.528, *p*= 0.228
%REM	21.90±6.61	22.61±3.27	19.31±5.14	F =2.259, *p*= 0.116
Number of awakings	23.50±6.38	23.56±10.27	20.68±10.52	χ^2=2.147, *p*= 0.342
Number of arousal	21.20+25.47	55.67±75.98	92.11±157.88	χ^2=3. 730, *p*= 0.155

Arousal index	3.29±3.94	8.12±10.95	14.17±23.99	χ^2=3. 611, *p*= 0.164
Number of arousal of NREM	20.10±25.74	53.50±76.03	90.00±158.10	χ^2=3.233, *p*= 0.199
Number of arousal of REM	1.10±1.60	2.17±2.75	2.11±2.73	χ^2=1.339, *p*= 0.512

Data are shown mean ± standard deviation (SD) or n (%).

GS, good sleeper; IWLM, insomnias with a low mismatch; IWHM, insomnias with a high mismatch

PSQI, Pittsburgh Sleep Quality Index; TST, total sleep time; SPT, sleep period time; SE, sleep efficiency; SOL, sleep onset latency; NREM: non-rapid eye movement; SWS, slow wave sleep; REM, rapid eye movement [a]*p*<0.05 versus GS.

Table 3- Comparison of absolute EEG spectral power among experimental groups(μv^2)

Variable	GS (n = 10)	IWHM (n = 18)	IWLM (n = 19)	Statistics
Frontal derivation				
Delta (1–4 Hz)	46.47±21.05	37.61±15.30	46.65±25.95	F =0.981, *p*= 0.383
Theta (4–8 Hz	3.23±1.32	6.54±10.21	4.89±2.77	χ^2=3.481, *p*= 0.175
Alpha (8–12 Hz)	2.14±1.09	2.47±0.91	3.55±2.54	χ^2=2.693, *p*= 0.260
Beta (15–20 Hz)	1.18±0.51	1.82±0.85	2.23±1.35[a]	χ^2=6.454, *p*= 0.040
Beta /Delta	3.19±2.45	5.68±4.42 [a]	9.34±20.25 [a]	χ^2=7.783, *p*= 0.020
Beta/Theta	38.15±11.93	56.80±37.98	49.26±23.47	χ^2=2.880, *p*= 0.237
Alpha/ Delta	5.32±3.26	7.66±4.93	20.75±57.75	χ^2=3.086, *p*= 0.214

Alpha/Theta	64.00±16.43	76.60±41.44	74.33±30.73	F =0.487, *p*= 0.618
Central derivation				
Delta (1–4 Hz)	37.99±12.36	33.89±19.01	46.48±20.94	F =2.154, *p*= 0.128
Theta (4–8 Hz	4.22±1.23	4.22±1.53	6.01±3.42	χ^2=2.872, *p*= 0.238
Alpha (8–12 Hz)	2.49±1.06	2.84±1.10	3.88±3.48	χ^2=0.710, *p*= 0.701
Beta (15–20 Hz)	1.76±0.48	2.59±1.07 [a]	2.82±1.22 [a]	F =3.480, *p*= 0.040
Beta/Delta	4.98±1.84	13.06±17.26 [a]	6.57±2.69	χ^2=6.861, *p*= 0.032
Beta/Theta	44.59±16.04	65.91±35.76	55.74±31.10	χ^2=4.860, *p*= 0.088
Alpha/Delta	6.87±2.90	14.20±20.91	8.76±8.42	χ^2=2.632, *p*= 0.268
Alpha/Theta	57.29±13.21	70.71±29.13	63.31±32.98	χ^2=1.774, *p*= 0.412

Data are shown as mean ± standard deviation (SD).

GS, good sleeper; IWLM, insomnias with a low mismatch; IWHM, insomnias with a high mismatch; [a]p<0.05 versus GS.

Table 4- Comparison of relative EEG spectral power among experimental groups

Variable	GS (n = 10)	IWHM (n = 18)	IWLM (n = 19)	Statistics
Frontal derivation				
Delta (1–4 Hz)	86.27±6.92	78.24±11.88	78.30±16.78	χ^2=3.820, *p*= 0.148
Theta (4–8 Hz	6.73±3.24	11.62±12.53	10.14±8.61	χ^2=5.243, *p*= 0.073
Alpha(8–12 Hz)	4.39±2.33	5.83±3.14	7.35±6.67	χ^2=2.805, *p*= 0.246
Beta(15–20 Hz)	2.61+1.71	4.30±2.85	4..21±2.14 [a]	χ^2=7.153, *p*= 0.028
Beta /Delta	3.19±2.45	5.68±4.42 [a]	9.34±20.25 [a]	χ^2=7.783, *p*= 0.020
Beta/Theta	38.15±11.93	56.80±37.98	49.26±23.47	χ^2=2.880, *p*= 0.237

Alpha/Delta	5.32±3.26	7.66±4.93	20.75±57.75	χ^2=0.214, *p*= 0.214
Alpha/Theta	64.00±16.42	76.60±41.44	74.32±30.73	F =0.487, *p*= 0.618
Central derivation				
Delta (1–4 Hz)	81.30±5.14	73.56±14.76	78.46±7.26	χ^2=3.587, *p*= 0.166
Theta (4–8 Hz	9.26±2.43	11.47±7.14	10.18±3.25	χ^2=0.342, *p*= 0.843
Alpha(8–12 Hz)	5.46±2.11	7.70±4.44	6.34±4.38	χ^2=2.483, *p*= 0.289
Beta(15–20 Hz)	3.99±1.30	7.28±4.62 [a]	5.02±1.52	χ^2=6.963, *p*= 0.031
Beta /Delta	4.98±1.84	13.06±17.26 [a]	6.47±4.37	χ^2=6.861, *p*= 0.032
Beta/ Theta	44.59±16.04	65.91±35.76	55.73±3.11	χ^2=4.860, *p*= 0.088
Alpha/ Delta	6.87±2.90	14.20±20.91	8.76±8.42	χ^2=2.632, *p*= 0.268
Alpha/ Theta	57.29±13.21	70.71±29.13	63.31±32.98	χ^2=1.774, *p*= 0.412

Data are shown as mean ± standard deviation (SD).

GS, good sleeper; IWLM, insomnias with a low mismatch; IWHM, insomnias with a high mismatch; [a]p<0.05 versus GS.

Table 5- Correlation between absolute EEG spectral power andSOD of TST

Variables	SOD of TST	
	r	*p*
Frontal derivation		
Delta (1–4 Hz)	0.157	0.290
Theta (4–8 Hz	0.114	0.447
Alpha (8–12 Hz)	0.024	0.871
Beta (15–20 Hz)	0.074	0.622
Beta / Delta	0.139	0.353
Beta/ Theta	0.217	0.142

Alpha/ Delta	0.102	0.495
Alpha/ Theta	0.179	0.229
Central derivation		
Delta (1–4 Hz)	0.114	0.445
Theta (4–8 Hz	0.029	0.539
Alpha (8–12 Hz)	0.047	0.752
Beta (15–20 Hz)	0.196	0.187
Beta / Delta	0.314	0.032
Beta/ Theta	0.190	0.200
Alpha/ Delta	0.256	0.083
Alpha/ Theta	0.264	0.073

SOD, Subjective-objective sleep discrepancy; TST, total sleep time.

Table 6- Correlation between relative EEG spectral power and SOD of TST

Variables	SOD of TST	
	r	*p*
Frontal derivation		
Delta (1–4 Hz)	0.202	0.172
Theta (4–8 Hz	0.153	0.305
Alpha (8–12 Hz)	0.141	0.343
Beta (15–20 Hz)	0.241	0.103
Beta / Delta	0.139	0.353
Beta/ Theta	0.217	0.142
Alpha/ Delta	0.102	0.495
Alpha/ Theta	0.179	0.229

Central derivation		
Delta (1–4 Hz)	-0.289	0.049
Theta (4–8 Hz	0.156	0.294
Alpha (8–12 Hz)	0.269	0.067
Beta (15–20 Hz)	0.373	0.010
Beta / Delta	0.314	0.032
Beta/ Theta	0.190	0.200
Alpha/ Delta	0.256	0.083
Alpha/ Theta	0.264	0.073

SOD, Subjective-objective sleep discrepancy; TST, total sleep time