Comparison of Polysomnography and Cardiopulmonary Coupling in the Diagnosis of Insomnia, Obstructive Sleep Apnoea, or Comorbidity, a Pilot Study

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Abstract: *Objective:* To verify the reliability of cardiopulmonary coupling (CPC) technology to diagnose chronic insomnia disorder (CID), obstructive sleep apnoea (OSA) and comorbid OSA with insomnia (COI).

Methods: Data from 161 patients suffering from the three conditions were collected, and objective sleep status was assessed simultaneously by CPC and polysomnography (PSG). These patients were diagnosed according to the clinical symptoms and PSG results. The general data of the three groups were compared, and the agreement of AHI and sleep parameters between CPC and PSG was analysed by Bland-Altman agreement plots.

Results: We found that, when AHI (events/h) ≥ 5, 10, 15, 20, 25 and 30 were used as the conditions for the diagnosis of OSA, the sensitivity was 82.7%, 63.5%, 67.3%, 84.6%, 71.9% and 61.5%; the specificity was 61.6%, 63.3%, 73.4%, 84.4%, 82.9% and 84.4%; and the area under the curve (AUC) was 0.792, 0.735, 0.787, 0.889, 0.884 and 0.861, respectively. Bland-Altman agreement plots for the sleep parameters were measured by PSG and CPC. Although 95% of the points of some graphs were within the consistency range, they were beyond the professionally acceptable threshold range.

Conclusion: As a tool for rapid screening of OSA patients, the overall performance of CPC is acceptable in subjects with clinical suspicion of OSA, but the clinical interpretation of sleep parameter results obtained with CPC must be cautious, especially in insomnia state.

Keywords: Cardiopulmonary coupling analysis, Insomnia, Obstructive sleep apnoea, Polysomnography.

INTRODUCTION

According to data from the World Health Organization, approximately 27% of the global population suffers from sleep disorders, and the prevalence of sleep disorders among Asian people is between 26.4% and 39.4% [1]. As a public health problem, sleep disorders have increased sharply in light of the increase in mental stress. Chronic insomnia disorder (CID) and obstructive sleep apnoea (OSA) are two of the most common sleep disorders. They often lead to drowsiness, fatigue, physical discomfort, cognitive impairment and so on, not only seriously affecting the social function of patients but also increasing the risk of chronic diseases. Although the aetiologies of CID and OSA are different, and the clinical manifestations vary widely, they often coexist clinically and are referred to as comorbid OSA with insomnia (COI) [2-4]. Compared with pure OSA or CID patients, COI patients exhibit more severe sleep disturbances and a higher prevalence of heart disease, and they have more frequent awakenings, difficulty falling asleep, daytime dysfunction and reduced quality of life [5].

In brief, the prevalence of CID, OSA and COI is high, and has serious clinical harm. A highly efficient diagnostic method could be conducive to early intervention, early treatment, and ultimately reduce the use of medical resources, and relieve the financial burden of patients. Unfortunately, the current clinical diagnostic tools for CID and OSA are limited [6, 7]. Polysomnography (PSG) is the gold standard for the diagnosis of sleep disorders. However, many limiting factors, such as high cost, tedious operation with many lead wires, poor compliance, and lack of instrument resources [8, 9], render PSG unable to be widely performed in clinical practice, resulting in a high missed diagnosis rate of OSA and other sleep-related diseases. Therefore, it is necessary to use a simpler and portable instrument to record sleep status. At this stage, to reduce the missed diagnosis rate of OSA and

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E-ISSN: 2409-3564/22

compensate for the usage limitations of PSG, a large number of researchers are committed to developing new portable equipment for sleep detection. However, it should be noted that the accuracy of existing portable detection equipment can vary due to the variety and different manufacturers, so they must rely on more evidence to prove their diagnostic accuracy.

Cardiopulmonary coupling (CPC) analysis was developed by the Thomas RJ team at Harvard Medical School in 2005 as a portable detection device for sleep monitoring and evaluation [10, 11]. The main principle of this method is to calculate the coupling relationship between heart rate variability (HRV) extracted from electrocardiography (ECG) and the ECG-derived respiration signal and to quantitatively evaluate sleep quality and screen for sleep-related breathing events using Fourier transform technology. Different from the apnoea hypopnea index (AHI) provided by PSG, the CPC-measured AHI (CPC-AHI) is obtained by analysing the duration and average frequency of low-frequency coupling (LFC). Due to the different calculation methods of the AHI between the two technologies, there have been some doubts about the clinical application of CPC in OSA diagnostic classification. Ma Y *et al*. [12] examined 205 outpatients who needed to be assessed for OSA and showed that CPC is an acceptable diagnostic method in OSA patients. Based on the severity of OSA in AHI, Mi Lu *et al*. analysed 179 subjects with suspected OSA and obtained receiver operating characteristic (ROC) curves of 0.79 (mild), 0.79 (moderate) and 0.86 (severe OSA) [13]. Another study showed that CPC identified patients with moderate to severe sleep apnoea with sensitivity of 100%, specificity of 81%, agreement of 93%, LR+ (positive likelihood ratio) of 5.20, LR− of (negative likelihood ratio) 0.00 and kappa of 0.85 compared with manual scoring of the AHI [14]. However, these studies did not include other related sleep disorders. We found that, in the study of CPC, there have been no intuitive comparisons of whether its sleep parameters are consistent with those of PSG, even in insomnia patients. At the same time, there have been no reports about the application of CPC in the COI population. Therefore, we conducted the current study to validate the use of CPC in patients with common sleep disorders and to assess its performance in Chinese patients in different groups (CID, OSA and their comorbidity). Another purpose of this study was to compare the sleep parameters measured by CPC with those measured by PSG, directly showing the similarities and differences in sleep quality between the two methods of sleep evaluation.

SUBJECTS AND METHODS

1. Subjects

From July 2018 to July 2020, inpatients suspected of having CID or OSA were consecutively collected, and demographic data, such as sex, age, and body mass index (BMI), was recorded. Of the 238 initial samples, only 161 met the criteria. The subjects were monitored by PSG and CPC simultaneously overnight. The CID patients met the ICSD-3 [6] diagnostic criteria, and PSG was used to exclude sleep-related diseases other than OSA (such as central and mixed sleep apnoea, sleep-related motor disorders, parasomnias, and rapid eye movement sleep behaviour disorder). The OSA patients met the diagnostic criteria of the American Academy of Sleep Medicine (AASM) [6, 7]; *i.e*., 5 ≤ AHI < 15/h is mild, 15 ≤ AHI < 30/h is moderate, and AHI ≥ 30/h is severe. COI patients simultaneously met the above criteria for CID and OSA. The exclusion criteria were as follows: serious arrhythmia (such as ventricular fibrillation, atrial fibrillation, degree II-III atrioventricular block) or other heart diseases (such as symptomatic coronary heart disease, congestive heart failure); chronic obstructive pulmonary disease or other serious lung diseases; PSG showing total sleep time (TST) < 4 h; poor quality of ECG and electroencephalogram (EEG) signals; continuous positive airway pressure ventilation; using oral appliances; and undergoing or undergoing surgery. This study was approved by the medical ethics committee of the Affiliated Chaohu Hospital of Anhui Medical University, and all of the subjects signed informed consent forms.

2. PSG

All of the subjects underwent nocturnal PSG for at least 7 hours in our sleep laboratory. The PSG was completed with Condi Grael v2 (Australia). The contents of sleep monitoring included EEG, II-lead ECG, electrooculography, electromyography, respiratory airflow, chest and abdomen movement, snoring, percutaneous oxygen saturation (SpO_2), leg movement and body position. There was also video surveillance. A professional PSG technician performed manual analysis of the data collected by the computer, strictly abiding by the criteria of the AASM, version 2.3, and obtained various sleep parameters and AHI. The PSG sleep measures consisted of TST, sleep efficiency (SE), sleep latency, wake time after sleep onset (WASO), times of rapid eye movement sleep

(REMs) and non-REM stages 1-3 (N1, N2, N3). The breathing measures consisted of AHI, blood oxygen saturation and other measures, such as leg motion index and heart rate.

3. CPC

CPC monitoring was completed using the AECG-600D instrument of Nanjing Fengsheng Yongkang Software Technology Co., Ltd. According to the number and frequency of HRV- and ECG-derived respiration coupling, the sleep spectrum of CPC was automatically generated by a computer, including high-frequency coupling (HFC, 0.1-0.4 Hz), LFC (0.01-0.1 Hz), enhanced LFC (the subpart of LFC) and very LFC (0-0.01 Hz). As an extension of PSG sleep staging technology based on EEG, CPC mainly describes sleep characteristics based on the interaction between the autonomic nerves and respiration, following the cyclic alternating pattern (CAP) in sleep. HFC in the sleep spectrum of CPC is related to the non-CAP EEG. When vagus nerve tension increases, the heart rate is relatively stable; breathing is stable; and blood pressure decreases, also known as stable sleep/deep sleep, and mainly occurring in part of N2 and all N3 as measured using PSG. While LFC is related to CAP in EEG, when sympathetic tension increases, breathing is relatively unstable, the heart rate fluctuates, and the blood pressure increases, also known as unstable sleep/light sleep. CPC analysis automatically generates an ECG-derived sleep spectrum, showing that non-REMs have an obvious bimodal structure, characterized by obvious alternation of high-frequency and low-frequency CPC intensity cycles. Normal REMs and wakefulness show very LFC characteristics, and fragmented REMs is part of LFC. Enhanced LFC mainly reflects apnoea/hypopnea and is positively correlated with the AHI. CPC can calculate the length of the corresponding spectrum during sleep by computer and obtain the data of the corresponding initial sleep time, light sleep (unstable sleep) time, deep sleep (stable sleep) time, awakening/REMs time, TST, SE and AHI [10, 14-16].

4. Statistical Analysis

Normally distributed data are represented by the mean ± standard deviation, and nonnormally distributed data are represented by *M* (*Q1, Q3*). The PSG and CPC data were normally distributed by the

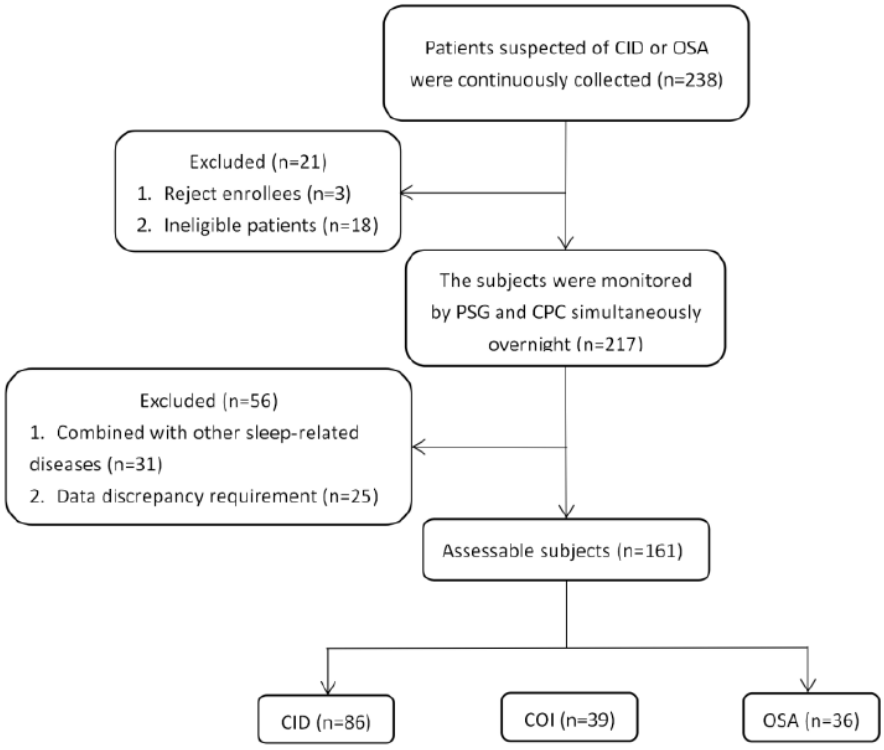

Figure 1: Flow-chart of the study design.

COI comorbid OSA with insomnia; CPC cardiopulmonary coupling; CID chronic insomnia disorder; OSA obstructive sleep apnoea; PSG polysomnography.

paired sample *t*-test, one-way ANOVA was used for multigroup comparisons, and data with nonnormal distribution was analysed by nonparametric testing. After controlling for confounding factors (sex, age, BMI), the correlations between the PSG-AHI, CPC-AHI and PSG-minimum SpO_2 in different subgroups of patients were analysed using partial correlation analysis. To evaluate the effectiveness of CPC technology in OSA screening, the sensitivity, specificity, positive predictive value, negative predictive value, LR+ and LR− were calculated when the CPC-AHI cut-off values were 5, 10, 15, 20, 25 and 30 events/h. ROC curves were also constructed for the same CPC-AHI cut-offs, as described above. To evaluate the agreement between the AHI obtained from PSG and CPC, intraclass correlation (ICC) and Bland-Altman agreement plots were conducted. Subgroup analysis was performed to evaluate the impact of different groups on the diagnostic accuracy of CPC technology. The Bland-Altman diagram was used to evaluate the agreement of sleep parameters obtained from the CPC and PSG instruments. $P<0.05$ was considered statistically significant. The analysis was completed using the Statistical Package for the Social Sciences, version 16.0 (Chicago, IL, USA).

RESULTS

1. Subject Characteristics

Two hundred thirty-eight patients participated in this study, and 161 subjects met the requirements. According to the clinical symptoms and PSG monitoring results, there were 86 cases of CID, 36 cases of OSA, and 39 cases of COI (see Figure **1**). Compared with OSA alone, the CID and COI patients were older and more often were women. However, there was no significant difference in BMI between the COI and OSA patients, both of whom were more obese than the CID patients. Detailed sleep monitoring data are shown in Table **1**.

2. Correlations between PSG-AHI, CPC-AHI and PSG-Minimum SpO_2

We pairwise analysed the correlations among PSG-AHI, CPC-AHI and PSG-minimum SpO_2 in the different groups by adjusting for sex, age, and BMI (see Table **2** with detailed results).

① PSG-AHI and PSG-minimum SpO_2. In all of the patients, the PSG-AHI had a moderate, positive correlation with the PSG-minimum SpO_2 (r=-0.537, p=0.000). Furthermore, this correlation was moderate in the OSA group (r=-0.534, p=0.001) and mild in the COI group (r=-0.377, p=0.023) but insignificant in the CID group.

② CPC-AHI and PSG-minimum SpO_2. In all of the patients, the CPC-AHI was mildly positively correlated with PSG-minimum SpO_2 (r=-0.379, p=0.000). Furthermore, in separate groups, only a moderate, positive correlation was found in the COI group (r=-0.592, p=0.000), and an insignificant correlation was found in both the CID and OSA groups.

Table 1: General Data of Subjects

	CID	COI	OSA	CID vs. COI	CID vs. OSA	COI vs. OSA
Sex, M/F	29/57	25/14	33/3			
Age (years)	50.2±11.9	52.2±12.7	44.4±11.7	0.390	0.016	0.006
BMI (kg/m^2)	22.1±2.9	25.7±3.4	26.0±2.0	0.000	0.000	0.980
TST (min)	401.3 (358.4, 436.4)	345.0 (303.5, 392.5)	410.0 (372.0, 454.5)	0.000	0.125	0.000
SE (%)	81.9 (75.5, 89.6)	75.7 (68.8, 83.9)	89.3 (83.2, 96.0)	0.210	0.006	0.001
Minimum S_PO_2 (%)	93.0 (90.0, 94.3)	78.0 (64.0, 87.0)	73.0 (72.3, 77.8)	0.000	0.000	0.985
Arousal index (/hr)	10.6 (4.8, 17.0)	20.3 (17.9, 24.2)	20.4 (14.8, 32.8)	0.000	0.000	0.912
PSG-AHI (/h)	0.4 (0, 1.1)	15.1 (11.1, 35.0)	24.4 (17.8, 55.6)	0.000	0.000	0.082
CPC-AHI (/h)	1.3 (0.4, 11.9)	26.9 (9.0, 53.7)	22.5 (5.5, 55.8)	0.000	0.000	0.955

AHI apnoea-hypopnea index; BMI body mass index; COI comorbid OSA with insomnia; CPC cardiopulmonary coupling; CID chronic insomnia disorder; OSA obstructive sleep apnoea; PSG polysomnography; SE sleep efficiency; SpO2 percutaneous oxygen saturation; TST total sleep time.

Table 2: Partial Correlation Analysis of CPC-AHI, PSG-AHI and PSG-Minimum SpO_2 in Different Groups of Patients (*r*)

	PSG-AHI and PSG-minimum SpO_2		CPC-AHI and PSG-minimum SpO_2	
	r	***p***	***r***	***p***
All patients (n=161)	-0.537	0.000	-0.379	0.000
CID (n=86)	-0.112	0.312	-0.018	0.872
COI (n=39)	-0.377	0.023	-0.592	0.000
OSA (n=36)	-0.534	0.001	-0.056	0.758

AHI apnoea-hypopnea index; COI comorbid OSA with insomnia; CPC cardiopulmonary coupling; CID chronic insomnia disorder; OSA obstructive sleep apnoea; PSG polysomnography; SpO_2 percutaneous oxygen saturation.

The above results were adjusted for sex, age and BMI.

3. Consistency between CPC and PSG for OSA Diagnosis

On the basis of the results of PSG diagnosis (divided into OSA and non-OSA based on whether PSG-AHI ≥5 events/h), when CPC-AHI (events/h) was at different levels, the sensitivity, specificity, positive likelihood ratio, and negative likelihood ratios of CPC for OSA diagnosis are shown in Table **3**. By ROC analysis (Figure **2**), the six curves are shown with the CPC-AHI cut-off points set at 5, 10, 15, 20, 25, and 30 events/h, and the area under the curve (AUC) was 0.792, 0.735, 0.787, 0.889, 0.884, and 0.861, respectively. The results proved that only when CPC used AHI (events/h) ≥ 20 as the cut-off point for OSA diagnosis was the consistency between CPC and PSG the best (AUC=0.889). The possibility of suffering from OSA increased, the sensitivity was 84.6%, and the specificity was 84.4%.

The intraclass correlation (ICC) for AHI between CPC and PSG was 0.580 (95% CI, 0.467–0.674). In the subgroup analysis, in the CID, COI and OSA groups, the ICCs for AHI between CPC and PSG were -0.004 (95% CI, -0.214–0.207), 0.589 (95% CI, 0.339–0.761), and 0.410 (95% CI, 0.099–0.649), respectively. The Bland-Altman agreement plots for AHI measured by CPC and PSG in all of the patients are presented in Figure **3a**, where the mean difference was 20.03 events/h, and 93.8% (151/161) of scatters were within the limits of agreement. We specifically produced the Bland-Altman agreement plots with the COI group, in which the mean difference was 20.25 events/h, and 97.4% (38/39) of scatters were within the limits of agreement (Figure **3b**). The Bland-Altman agreement plots with moderate-to-severe OSA (PSG-AHI ≥ 15/h) patients showed a mean difference of 24.96 events/h, and 92.3% (48/52) of scatters were within the limits of agreement (Figure **3c**).

Table 3: Performance of CPC Relative to PSG in the Diagnosis of OSA (n=161)

CPC-AHI(/h) cut-off	n	TP	FP	FN	TN	Sen (%)	Spe (%)	LR+	LR–
≥ 5	75	62	33	13	53	82.7	61.6	2.15	0.28
≥ 10	63	40	36	23	62	63.5	63.3	1.73	0.58
≥ 15	52	35	29	17	80	67.3	73.4	2.53	0.45
≥ 20	39	33	19	6	103	84.6	84.4	5.42	0.18
≥ 25	32	23	22	9	107	71.9	82.9	4.20	0.34
≥ 30	26	16	21	10	114	61.5	84.4	3.94	0.46

CPC-AHI (/h) ≥5, ≥10, ≥15, ≥20, ≥25, ≥30, all subjects at greater than the diagnostic cut-off point of OSA by CPC with 5, 10, 15, 20, 25 and 30 as diagnostic cut-off points, respectively; AHI apnoea-hypopnea index; CPC cardiopulmonary coupling; FN False Negative; FP False Positive; LR+ positive likelihood ratio; LR– negative likelihood ratio; OSA obstructive sleep apnoea; PSG polysomnography; Sen sensitivity; Spe specificity; TN true negative; TP true positive.

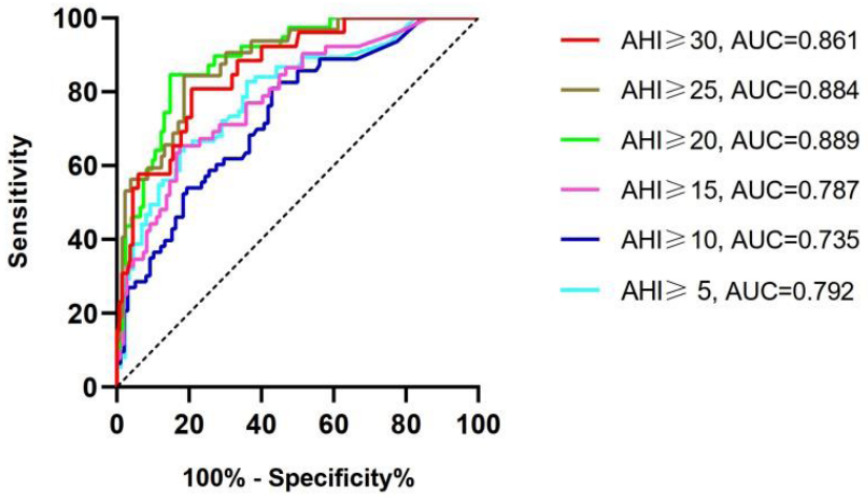

Figure 2: Receiver operating characteristic curves for CPC-AHI versus PSG-AHI.
AHI apnoea-hypopnea index; AUC area under the curve; CPC cardiopulmonary coupling; PSG polysomnography.

4. The Agreement of Sleep Parameters Obtained from CPC and PSG

The Bland-Altman agreement plots for sleep parameters measured by CPC and PSG are presented in Figure **4**. In non-REMs time, the mean difference was 72.7 min, the 95% consistency limit was (-135.9, 149.2), and 96.3% (155/161) was within the limit. In REMs time, the mean difference was -33.1 min, the 95% consistency limit was (-117.8, 51.7), and 95.7% (154/161) was within the limit. In the TST, the mean difference was -26.2 min, the 95% consistency limit was (-156.6, 104.1), and 93.2% (150/161) was within the limit. In WASO, the mean difference was 37.1 min, the 95% consistency limit was (-71.8, 146.0), and 93.8% (151/161) was within the limit. In SE, the mean difference was -5.6%, the 95% consistency limit was (-61.9, 50.8), and 100% (161/161) was within the limit.

DISCUSSION

In this study, CPC and PSG were used to perform sleep monitoring in patients with CID, OSA and both comorbid diseases simultaneously to evaluate the accuracy of CPC technology in OSA screening and to compare the consistency of sleep parameters measured by CPC and PSG.

According to the comprehensive evaluation of OSA and CID by patients' chief complaints, medical history and results from PSG, this study found that the percentage of OSA in the CID population was approximately 31.2% (39/125), while 52.0% (39/75) of OSA patients presented insomnia symptoms, similar to previous research conclusions [5, 17, 18]. The reasons for the high prevalence of CID and OSA complications could be the following. (1) Studies have shown that insomnia is the outcome of an active hypothalamic pituitary adrenal (HPA) axis and an excited sympathetic system. OSA causes HPA axis activity through self-activation and repeated awakening at night, and it further promotes the occurrence of insomnia [19, 20]. (2) Repeated apnoea leads to sleep fragmentation and awakening, destroys the continuity and periodicity of sleep, and causes fragmentation and superficial sleep processes. Prior studies have noted the importance of OSA compared with simple OSA, and OSA patients with insomnia are more prone to psychological disorders (such as depression), obvious sleep structure disorders, and other diseases, such as restless legs syndrome [21, 22]. In Table **1**, we can see that, compared with OSA patients, COI sufferers had lower TST and SE. However, there were similar AHIs and awakening times between the two groups. This result was consistent with those from previous studies [5]. In addition, we found that COI patients had low oxygen saturation as OSA patients. These findings indicated that, in COI patients, the insomniac features are more similar to those in CID patients, but they are also standard OSA sufferers according to oxygen desaturation. Therefore, clinicians should pay more attention to sleep quality and daytime function, as well as the relatively poor prognosis of COI patients.

In the current study, one of the purposes was to evaluate the accuracy of CPC relative to PSG in the diagnosis of OSA. We found that the device has moderate sensitivity for the diagnosis of OSA with CPC-AHI (events/h) ≥ 5, but the specificity is not high.

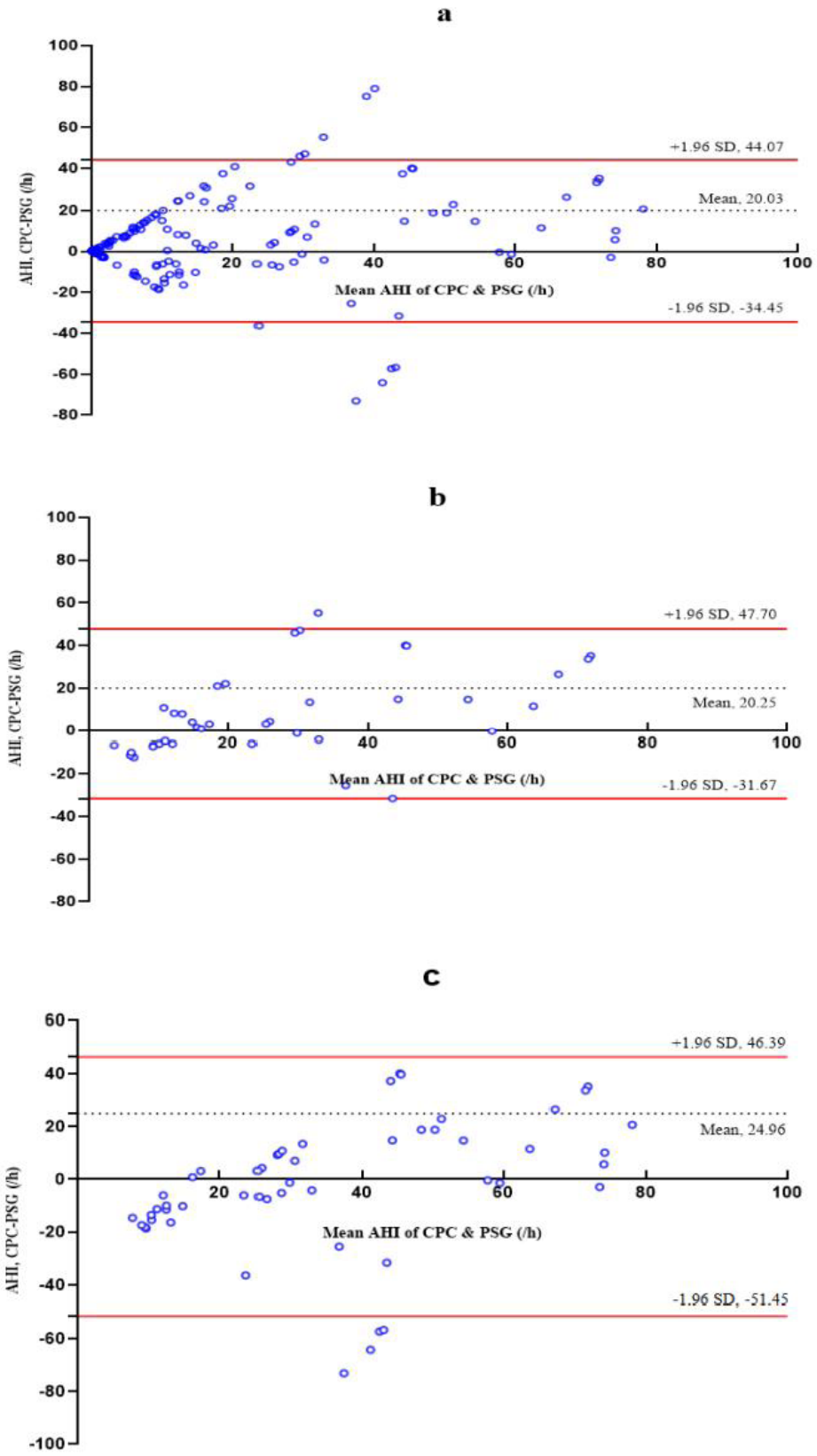

Figure 3: Bland-Altman agreement plots for the AHI measured by PSG and CPC. a In all of the patients. b In the COI patients. c In the moderate-to-severe OSA (PSG-AHI ≥ 15/h) patients.

AHI apnoea-hypopnea index; COI comorbid OSA with insomnia; CPC cardiopulmonary coupling; CID chronic insomnia disorder; OSA obstructive sleep apnoea; PSG polysomnography.

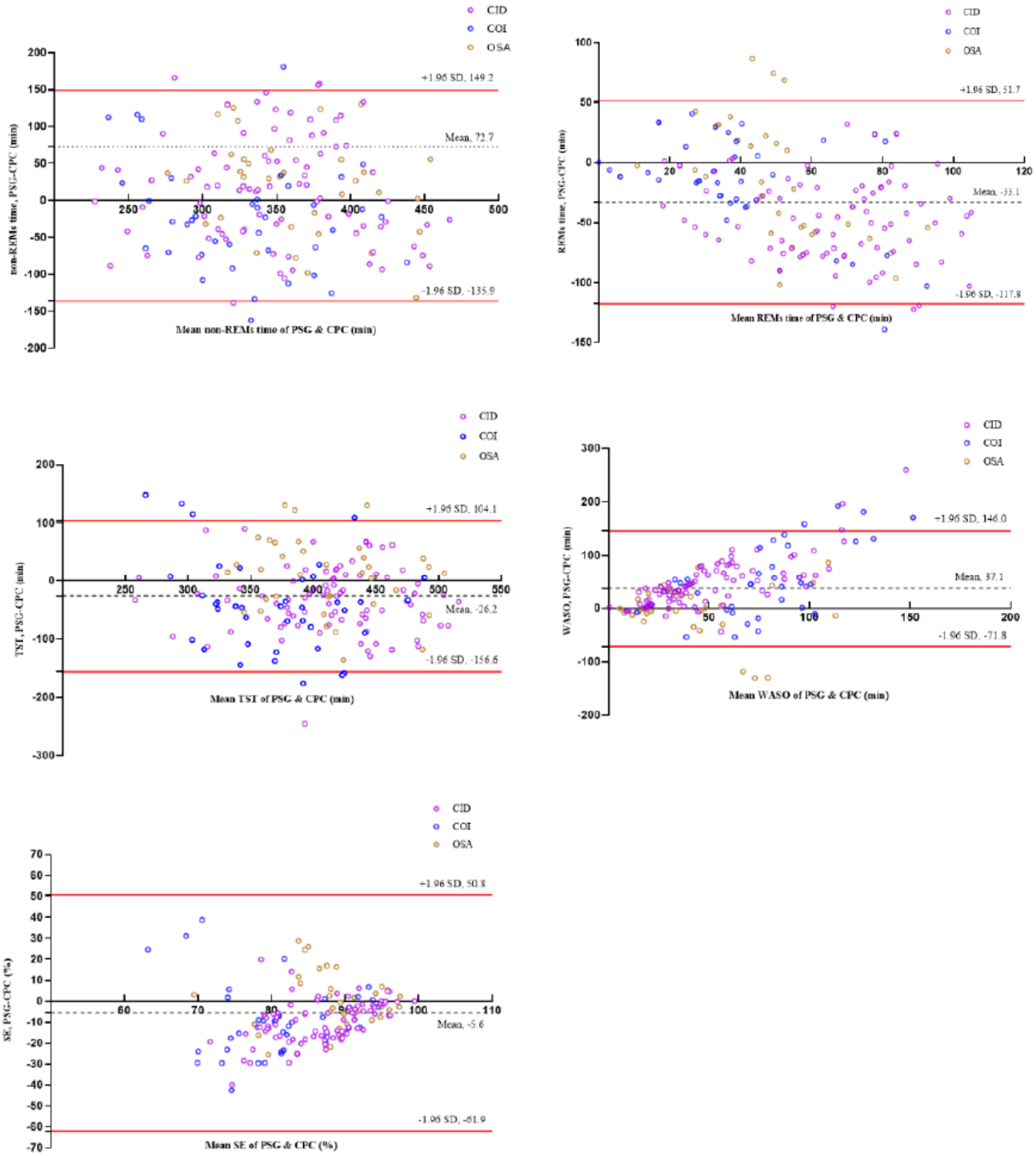

Figure 4: The agreement of sleep parameters obtained from CPC and PSG.

CID Chronic insomnia disorder; COI comorbid OSA with insomnia; CPC Cardiopulmonary coupling; OSA obstructive sleep apnoea; PSG polysomnography; REMs rapid eye movement sleep; SE sleep efficiency; TST total sleep time; WASO wake time after sleep onset.

When CPC-AHI (events/h) ≥ 20, the possibility of suffering from OSA increases, and its sensitivity and specificity are 84.6 and 84.4, respectively (see Table **3** and Figure **2**). These results were similar to those of Xie M *et al*., who also found that, when AHI (events/h) ≥ 5, 10, 15, 20 and 30 was used as the condition for the diagnosis of OSA, the sensitivity was 0.82, 0.93, 0.96, 0.96 and 0.77; the specificity was 0.50, 0.75, 0.72, 0.80 and 0.86; and the AUC was 0.868, 0.892, 0.915, 0.942 and 0.921, respectively [23]. The consistency of the AHI measured by PSG and CPC was moderate (ICC=0.58). However, through further

Bland-Altman analysis, we found that the mean difference was 20.03 events/h, the 95% consistency limit was (−34.5, 44.1), and only 93.8% of scatters were located within the limits of agreement, indicating poor consistency between the CPC-AHI and PSG-AHI. It would therefore be interesting to study the consistency of subgroups. The reasons for poor consistency between CPC-AHI and PSG-AHI might be as follows. (1) The calculations of CPC-AHI and PSG-AHI are distinct. The CPC-AHI is calculated by multiplying the average sleep time of the LFC by the average frequency [11]. Any low-frequency stimulation (such as the external environment) can cause an increase in the partial energy of LFC, which could affect the AHI calculated by CPC. (2) Patients with a higher AHI might have more serious cardiovascular diseases, which would lead to reduced heart rate variability, thus affecting CPC diagnostic accuracy [24]. (3) There are differences between instrumental and manual readings. The CPC-AHI is generated by automatic instrumental analysis, while the PSG-AHI is generated by manual interpretation. However, these parameters of CPC in our study were generally “low” compared with previous studies [12-14, 23]. This difference might have been due to the greater number of CID patients in this study and the insensitivity of CPC in patients with lower AHI (as indicated in our results). The correlation coefficient between PSG-AHI or CPC-AHI and PSG-minimum SpO_2 was not high, which might be related to the small sample size of our subgroup (COI and OSA). Contrary to expectations, this study found no correlation between CPC-AHI and PSG-minimum SpO_2 in COI patients (see Table **2**). Another important finding was that the application of CPC-AHI in pure OSA patients incurs a high risk of missed diagnosis, especially in some severe patients whose "AHI is mildly high but SpO_2 is very low". The predictive value of OSA screening deserves further study.

Another purpose of this study is to assess the consistency of CPC relative to PSG in the detection of sleep quality under different conditions. Some studies have used CPC to compare sleep patterns between CID or OSA sufferers and healthy people [25-27], but no studies comparing CID, OSA and COI have yet been found. Our study found that the sleep parameters provided by CPC might not well reflect the sleep stage of patients. The application of Bland-Altman analysis could directly reflect the real situation. The absolute values of the maximum errors within the consistency limits were non-REMs time 146.0 min, REMs time 103.0 min, TST 144.5 min, WASO 139.0 min and SE 42.5%, which were clinically unacceptable. The mean differences between CPC and PSG sleep parameters were non-REMs time 72.7 min, REMs time −33.1 min, TST −26.2 min, WASO 37.1 min and SE −5.6%, which were not close to 0, indicating that there was a significant difference between the two. Through further Bland-Altman analysis, we realized that, in all of the patients, the mean non-REMs time and WASO obtained by CPC were lower than those obtained by PSG, in which the REMs time and TST were higher than those from PSG. The possible reasons are the following. (1) CPC mainly evaluates the awakening or REM_S status of patients by body movement. For awake patients with immobile bodies, CPCs interpret their arousal status as REMs, resulting in decreased WASO and increased REMs time, causing significantly increased TST and SE. (2) The work mechanisms of CPC and PSG are different. In CPC, the analysis result reported is not based on the traditional non-REM stage but divides sleep into light sleep (unstable sleep, corresponding to the LFC part in CPC analysis), deep sleep (stable sleep, corresponding to the HFC part in CPC analysis), and awake or REM stage (corresponding to the VLFC part in CPC analysis). Therefore, CPC mainly evaluates the stability and continuity of sleep, and the specific stages of sleep are not good. Therefore, we must be cautious in the clinical interpretation of the sleep parameter results obtained by CPC.

LIMITATIONS AND PROSPECTS

This study has several limitations worth discussing. First, there is no repeated measure on the same sample, and PSG had a “first night effect”, which cannot correctly reflect the original sleep quality of the patient. Second, the sample size of the subgroups was small, especially in the COI and OSA groups. Therefore, larger sample studies are expected in the future. Third, based on the DSM-5 and ICSD-3, the diagnosis of insomnia is based on self-reported symptoms, which are subjective, while only the measurement results of CPC and PSG were compared in our analysis. We used a the MINI-International neuropsychiatric interview to exclude patients with significant anxiety and depression, but did not compare subgroups, which is unfortunate because it has been shown that COI patients are more likely to have emotional problems. Future comparative studies are encouraged to use different portable methods of home testing. The results of the current study suggested that the sleep parameters obtained by CPC might not be

evaluated by traditional sleep stages, and more samples from different populations are needed to prove their utility in screening for OSA. In the future, CPC could be combined with other monitoring methods, such as blood oxygen detectors and actigraphy, to improve its diagnostic value.

CONCLUSION

As a tool for rapid screening of OSA patients, the overall performance of CPC is acceptable in subjects with clinical suspicion of OSA, but the clinical interpretation of sleep parameter results obtained with CPC must be cautious.

ACKNOWLEDGEMENTS

This work was financially supported by the National Natural Science Foundation of China (81370444 and 81671316). The authors would like to thank all of the staff members of the Sleep Disorders Department of the Affiliated Chaohu Hospital for their contributions to this work.

ETHICAL APPROVAL AND INFORMED CONSENT

This study was approved by the Medical Ethics Committee of the Affiliated Chaohu Hospital (Anhui Medical University, Hefei, China). All of the procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

FUNDING

The work was supported financially by the National Foundation of Nature Science of China (81671316)

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

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Received on 17-07-2022 Accepted on 10-08-2022 Published on 13-08-2022

http://dx.doi.org/10.15379/2409-3564.2022.09.02.01