Sleep Science 9 (2016) 84–88

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Sleep Science

journal homepage: www.elsevier.com/locate/ssci

Full length article

Sleep architecture alterations in patients with periodic limb movements disorder during sleep and sleep breathing disorders

Virginia Mancebo-Sosa, Viridiana Mancilla-Hernández, Joana Miranda-Ortiz, Aremy Hernández-Torres, Romel Gutierrez-Escobar, Adrian Poblano *, Ulises Jiménez-Correa

Clínic of Sleep Disorders, School of Medicine, National University of Mexico, Mexico City, México

ARTICLE INFO

Article history:
Received 10 February 2016
Received in revised form
5 April 2016
Accepted 22 June 2016
Available online 7 July 2016

Keywords:
Periodic limb movements disorder
Obstructive sleep apnea-hypopnea syndrome
Sleep architecture
Polysomnography

ABSTRACT

Introduction: Sleep movement disorders includes mainly periodic limb movement and others. The more frequent breathing disorders are: obstructive sleep apnea-hypopnea syndrome and primary snoring.
Objective: To compare sleep architecture in periodic limb movements and breathing disorders of different severity, and weight their interactions.
Methods: We compared sleep architecture in 160 patients, divided in six groups: periodic limb movements (n=25), obstructive apnea only (n=30), periodic limb movements/snoring (n=30), periodic limb movements/mild apnea (n=25), periodic limb movements/moderate apnea (n=25), periodic limb movements/severe apnea (n=26). Polysomnographic variables were compared by analysis of variance and Tukey test.
Results: We observed an increase of percentage of awakenings in the group with periodic limb movements/severe apnea. We found an increase of percentage of light sleep in the group with obstructive apnea only with respect to periodic limb movements group. The group with obstructive apnea only presented less rapid eye movements sleep in relation with group with periodic limb movements. We found an increase of awakenings in the group with periodic limb movements/severe apnea to the group with periodic limb movements only. Oxygen saturation showed a decrease in the group with periodic limb movements/severe apnea and obstructive apnea only group to periodic limb movements only group.
Conclusions: Periodic limb movements and breathing disorders, resulted in more additive changes in sleep architecture alterations, than as separately disorders, in a complex interaction. Research in these relations deserve more investigations.

1. Introduction

Sleep disorders are divided in six groups according to the new Third International Classification of Sleep Disorders [1]. Sleep breathing disorders (SBD) are in the second group, and Sleep movement disorders (SMD) are in the fifth group of this classification.

SMD are characterized by burst of repetitive, involuntary, and stereotyped movements of toe, and partial flexion of ankle, knee, and hip during sleep [2]. Periodic limb movement disorder during sleep (PLMs) is the more frequent alteration in this group. Alterations could be due to abnormal inhibition of motor system during sleep. SMD has a reported prevalence of 7.6% in adult patients [3].

In the SBD group, we can found more frequently, the Obstructive sleep apnea-hypopnea syndrome (OSAHS), and Primary snoring (PS). OSAHS main characteristics are: repetitive and intermittent events of obstruction of the Superior air pathway (SAP), which results in complete (apnea) or partial (hypopnea) events $\geq$ 10 s (sec) of interruption of air flux, with a decrease of blood oxygen saturation and an increase of body, and breathing movements, and snoring [4]. Obstruction is secondary to abnormal narrowing or collapse of SAP during sleep, and tone loss of pharyngeal muscles [5]. Higher frequency of SBD was present in males than females. In one study carried-out in Latinamerica [6], authors reported OSAHS prevalence of 3.2%, and 54.8% for PS.

PLMs and OSAHS can be associated to cortical awakening or autonomic activation. However, some body movements can be found during, or behind to an apnea event, and can difficult their identification to clinicians. Moreover, in the upper airway resistance syndrome (UARS), the component event could be a respiratory effort

* Correspondence to:148 Col. Doctores, Delegación Cuahutémoc, México D.F., C.P. 06720, Mexico.
E-mail address: drdislexia@yahoo.com.mx (A. Poblano).
Peer review under responsibility of Brazilian Association of Sleep.

http://dx.doi.org/10.1016/j.slsci.2016.06.002

related arousal (RERA), and PLMs, the component event cold be a repetitive, stereotyped extremity movements occurring in a periodic fashion, associated in certain patients, by this reason is very important to be differentiated between the disorders [7]. PLMs and OSAHS can result in sleep architecture (SA) alteration, and could be detected by means of Polysomnographic (PSG) recordings.

Researchers found a frequency of PLMs of 24–48% of patients with OSAHS [8]. Co-existence of both disorders has been recognized long-ago, but there is a wide controversy on their interaction. Thus, the objective of this research was to compare SA alteration in a group of patients with PLMs, and SBD, and both alterations, studied by means of PSG recordings, and to weight their interaction.

2. Method

2.1. Subjects

We performed a descriptive, and comparative study at the Clinic of Sleep Disorders at the National University of Mexico. Patients with PLMs were diagnosed when fulfilling the American Sleep Medicine Association criteria, while patients with SBD: OSAHS and PS were identified after complete fulfilling criteria in the same way. Inclusion, exclusion, and elimination criteria for each group are presented in Table 1. The sample was constructed as follows: 160 patients (51% females, and 49% males), with a mean age ($\pm$ Standard deviation) of 53.9 ± 14.9 years, with age range of 19–83 years. Sample was divided in six groups: PLMs (n=25), OSAHS only (n=30), PLMs/PS (n=30), PLMs/mild OSAHS (n=25), PLMs/moderate OSAHS (n=24), and PLMs/severe OSAHS (n=26), demographic features of each group are show in Table 2. Protocol of the study was approved by the Research and Ethics Committee of the institution. Informed consent was obtained in every subject after a wide explanation of the research and importance of their participation. Patients and control subjects signed informed consent according to Declaration of Helsinki.

Table 1
Inclusion, exclusion, and elimination criteria of subjects of each group of the sample.

Group	PLMs	OSAHS	PLMs/PS	PLMs/OSAHS		
				mild	moderate	severe
Inclusion						
Age > 18 years	✓	✓	✓	✓		
Complete PSG (8 h)	✓	✓	✓	✓		
Meets PSG criteria for	✓	✗	✓	✓		
PLMs*	✗	✓	✗	✓		
Meets PSG criteria for	✗	NA	✓	NA		
OSAHS**	✓	✓	✓	✓		
Meets PSG criteria for PS						
Under medical control for heart, metabolic, and kidney diseases						
Exclusion						
PSG by splint night	✓	✓	✓	✓		
PLMs index < 15 movements/h	✓	NA	✓	✓		
Elimination						
To develop other neurological diseases	✓	✓	✓	✓		

OSAHS=obstructive sleep apnea-hypopnea syndrome. PLMs=periodic limb movements during sleep disorder. PS=primary snoring. PSG=polisomnography. NA=not apply. ✓=present, ✗=absent.

2.2. Polysomnography (PSG)

All night Polysomnographic (PGS) recordings were performed with digital Polysomographic devices Alice, with Sleepware version 2.8.78 (Respironics Inc. EUA). For electroencephalographic (EEG) recording, we set five silver plate surface electrodes in F4, C4, O2, Cz and A1 according to the International 10–20 System [9]. Electromyographic (EMG) recordings were obtained by means of skin plate electrodes located on chin and over tibialis muscles of both legs. Electro-oculographic (EOG) recordings were obtained from skin electrodes placed in lateral canthi of each eye. For Electrocardiogram (EKG) recordings, we placed disposable surface electrodes over second intercostal space and mid-clavicular line. Respiratory flow was measured by means of a thermistor in nostrils, and pletismographic belts in thorax and abdomen (Pro-Tech, Velcro Strap). Oxygen saturation was measured with a pulse oxymeter (Masimo Set), and snoring with a microphone (Pro-Tech).

Interpretation of the PSG recording was carried-out by qualified technicians following standards of the American Association of Sleep Medicine for sleep scoring and associated events [10]. Compared variables included as follows: Total sleep time (TST), Sleep latency (SL), SL to Rapid eye movements sleep (REMs) (SL-REMs), Sleep efficiency (SE), Awake percentage (A%), Percentage of light sleep in N1-N2 stages (N1%), and in deep sleep in N3 stage (N3%), and in REMs (REM%), Awakenings (A), and Snoring (S).

In patients with PLMs we measured number of movements/hour of sleep, or index of severity of PLMs, as follows: mild (15–25 movements (mov)/hour (h); moderate (26–50 mov/h), and severe ($\geq$ 51 mov/h). In patients with OSAHS we calculated Apnea-hypopnea index (AHÍ), classified as follows: mild (6–15 events/hour), moderate (16–30 events/h), and severe degree ($\geq$ 31 events/h).

2.3. Epworth sleepiness scale (ESS)

We utilized the Epworth sleepiness scale (ESS). The instrument measures sleep propensity in awake state, in order to identify individuals with daytime excessive sleepiness (DES). The EES is a simple self-administrated questionnaire (eight questions), that asks the subject to rate on a scale of 0–3, the chances of sleep in eight different situations commonly met in daily life (sum of eight questions can vary from 0 to 24). Scores > 10 are considered as abnormal sleepiness. The EES has been validated in México [11].

2.4. Statistical analysis

We calculated mean (x), and Standard deviation (SD) of quantitative variables. For qualitative variables we calculated percentages (%). We used one-way Analysis of variance (ANOVA) to compare means across groups, and the Tukey honest differences test *post-hoc* to found location of significant differences. We chose an *alpha* value of $p \leq 0.05$ to select differences as significant.

3. Results

PSG variables in the six studied groups are presented in Table 3. We found high values of awake percentage to reference standards in all groups, however, group of patients with PLMs/severe OSAHS showed a significant increase of this percentage compared to PLMs/mild OSAHS ($F=2.31$, $gl=5154$; $p=0.04$). We observed an increase in percentage of light sleep (N1-N2) in all groups, however, group with OSAHS only, has a significant increase, to PLMs group ($F=3.00$; $gl=5, 153$; $p=0.01$). Although percentage of REMs was decreased in all groups, we found that group with OSAHS only, had a significant decrease to group with PLMs ($F=2.83$; $gl=5154$; $p=0.01$). We observed an increase of awakenings in all

Table 2
Demographic data of subjects in each group of the sample.

Group	PLMs	OSAHS	PLMs/PS	PLMs/OSAHS	PLMs/OSAHS	PLMs/OSAHS	F	p
	(n=25)	(n=30)	(n=30)	mild (n=25)	moderate (n=24)	severe (n=26)		
Gender (%)								
Female	72	43	60	48	46	35		
Male	28	57	40	52	54	65		
Age (years)	46.6 ± 3.3	52.2 ± 2.3	52.2 ± 2.5	53.6 ± 2.7	58.1 ± 2.9	61 ± 2.8	3.08	0.01
BMI (kg/m²)	24.1 ± 2.6	30.1 ± 1.4	28 ± 2.2	23.6 ± 2.4	23.9 ± 2.5	28.9 ± 2.0	1.69	0.13

PLMs=periodic limb movements during sleep disorder. OSAHS=obstructive sleep apnea-hypopnea syndrome. PS=primary snoring. BMI=body mass index.

Table 3
Comparison of polysomnographic variables among patients with Periodic limb movements during sleep (PLMs) disorder and Sleep breathing disorders.

Variables PSG	PLMs (n=30)	OSAHS (n=25)	PLMs/PS (n=30)	PLMs/OSAHS mild (n=25)	PLMs/OSAHS moderate (n=24)	PLMs/OSAHS severe (n=26)	F	p	Post hoc test
TST (min)	376.4 ± 17.7	365.5 ± 14.4	389 ± 15.7	400.6 ± 12	373.5 ± 15.8	333.6 ± 17.2	2.11	0.06	4 > 6
Latency to sleep (min)	21.5 ± 2.6	24.8 ± 7.8	21.9 ± 3.2	24 ± 4.0	22.9 ± 2.7	26.5 ± 5.7	0.14	0.98	
Latency to REMs (min)	151.8 ± 23.0	172.0 ± 20.3	163.4 ± 18.6	121.3 ± 14.9	152.1 ± 20.6	156.4 ± 19.3	0.76	0.57	
Sleep eficiency (%)	77.7 ± 3.7	75.8 ± 2.9	79 ± 3.6	82.6 ± 2.3	78.6 ± 3.2	70.1 ± 3.5	1.55	0.17	4 < 6
Awake time (%TST)	18.4 ± 3.7	23.8 ± 2.9	17.6 ± 2.7	15.5 ± 2.4	22.6 ± 3.1	28.6 ± 3.6	2.31	0.04*	
Sleep periods (%TST)									
Light sleep (min. N1-N2)	60.8 ± 2.3	71.8 ± 1.9	66.2 ± 2.3	66.7 ± 1.6	67.7 ± 1.8	68.1 ± 2.0	3.00	0.01*	1 > 2
Deep sleep (min. N-3)	19.4 ± 2.1	13.8 ± 1.1	16.9 ± 1.5	16.7 ± 1.3	16.5 ± 1.4	16.4 ± 1.6	1.31	0.26	1 < 2
REMs	19.3 ± 1.2	13.3 ± 1.1	14.7 ± 1.1	16.6 ± 1.1	15.4 ± 1.0	15.3 ± 1.2	2.83	0.01*	
Awakenings (no./TST)	99.6 ± 13.7	170.9 ± 23.9	133.6 ± 20.1	141.4 ± 13.9	177 ± 20.6	211.5 ± 24.7	3.53	< 0.001*	1 < 2, 2 < 6
ESS	5.6 ± 1.0	6.7 ± 1.0	6.1 ± 1.0	4.2 ± 1.1	6.8 ± 1.1	9.3 ± 1.5	2.00	0.08	
AHI	2.1 ± 0.3	45.4 ± 2.7	2.3 ± 0.3	10.4 ± 0.5	23 ± 0.8	46.6 ± 3.8	102.2	< 0.001*	
PLM index mov./h	34.2 ± 4.0	0.2 ± 0.1	41 ± 4.3	42.8 ± 6.0	40.4 ± 5.6	34.3 ± 3.2	16.11	< 0.001*	
Snorings/TST	0.0 ± 0.0	344.4 ± 65.3	291.9 ± 39.1	180.8 ± 34.4	232.1 ± 43.1	260.5 ± 45.8	7.22	< 0.001*	

PLMs=periodic limb movements during sleep disorder. OSAHS=obstructive sleep apnea hypopnea syndrome. PSG=polisomnography. REMs=rapid eye movements sleep. ESS=Epworth sleepines scale. AHÍ= apnea-hypopnea index. TST=total sleep time. min.=minutes. h=hours.
* significant probability

Table 4
Comparison of sleep cardio-respiratory variables among patients with Periodic limb movements during sleep (PLMs) disorder and Sleep breathing disorders.

Variable	PLMs (n=25)	OSAHS (n=30)	PLMs/PS (n=30)	PLMs/OSAHS mild (n=25)	PLMs/OSAHS moderate (n=24)	PLMs/OSAHS severe (n=26)	F	p	Post hoc test
O_2 saturation (%)									
Average	92.9 ± 0.4	88.6 ± 1.3	89.8 ± 0.6	91.3 ± 0.5	91 ± 0.5	89.1 ± 1.1	3.14	0.01*	1 < 2 > 6
Minimum	82.3 ± 3.6	70 ± 3.3	78.5 ± 3.3	79.5 ± 3.54	72.7 ± 4.9	77.6 ± 1.0	1.74	0.12	
HR average (bpm)	66.3 ± 2.0	69.7 ± 3.5	65.5 ± 3.6	60.6 ± 4.4	63.1 ± 2.4	66 ± 2.6	0.87	0.49	

PLMs=periodic limb movements during sleep disorder. OSAHS=obstructive sleep apnea hypopnea syndrome. O_2=oxygen. HR=Heart rate. bpm=beats per minute.
* significant probability.

groups, although, group with PLMs/severe OSAHS, showed the greater increase, with respect to group with PLMs (F =3.53; gl=5154; p=0.005), see Table 3.

PLMs index, AHÍ, average of snoring/h, and Total sleep time (TST) showed significant differences as expected by the inclusion criteria of groups (see Table 3). Cardio-respiratory variables showed a decrease percentage of oxygen saturation in the group of PLMs/severe OSAHS and OSAHS only, in relation with group of PLMs only (F=3.14; gl =5153; p=0.01), see Table 4.

4. Discussion

4.1. Main findings and clinical relevance

Our data showed SA alterations, reflected by PSG changes in patients with PLMs disorder, and SBD, and the interactions among both disorders, and how these changes may result in clinic and functional alterations in patients with both sleep disorders. Clinical usefulness of our research comes from the fact that frequently, these alterations are found together in the same patient. Many times, clinicians give more importance to OSAHS, and left aside therapeutics of PLMs disorder, with a failure of overall treatment of the patient. Our data suggest benefits of the therapeutics of both disorders, clinician must be alter, and classify adequately each disorder, avoiding confusion in diagnosis with the current criteria [1,10] because the main concern could be confusion among PLMs, and movements related to increased airway resistance. We know that in literature are controversial points of view of the interaction, and the role of each, PLMs and OSAHS in SA alteration, thus our study design of six groups, allow us, to weight relevance of PLMs disorder, OSAHS only, PS, and OSAHS severity, separately.

4.2. Comparison with other studies and explanations

Many studies identified positive associations between PLMs and SBD in different measures of PSG alterations. However, measures and tools used to quantify them have varied among studies predicting different outcomes. Events of PLMs can be found before, during, or after OSAHS awakenings, unknowing if are cause, effect, or simultaneous phenomena. These facts generate the controversy if movements itself results in SA alteration and/or Sleep quality (SQ) alteration. According to the Scoring manual of the American Academy of Sleep Medicine, PLMs must be identified when are not associated to a SBD, with an interval >0.5 s among awakening and movement, to be considered as independent. In our observation, we found an increase of awakenings in patients with both disorders (PLMs/severe OSAHS). Thus, our data suggest that PLMs and severe OSAHS had the more additive relationship than each disorder separately, and contribute to alter SA and SQ.

Several studies had demonstrated that PLMs results in autonomic activation related to a Cyclic alternating pattern (CAP), identified in EEG recordings. CAP may be used as an sleep mark of excitation or instability [12]. However, in our study, we had not complete EEG recording to identify CAP, and their frequency in our recordings.

As is well known, SBD may result in sympathetic activation, that produce involuntary movements after an apnea event, and an sleep continuity disruption, manifested by DES [13]. These movements maintain patients with OSAHS in light sleep, with a decreased threshold for awake, fact that explain the higher percentage of awake time found in our group of PLMs/severe OSAHS, as cumulative effect of both disorders in SA, because these movements are produced not only by respiratory alterations, instead, they are also generated by the motor disorder. Thus we saw that alterations were higher and resulted in an increase of light sleep and awakenings. Indeed, we observed an awakenings increase in our sample, probably related to DES. Awakenings were the result of brainstem nuclei activation engaged in sleep control, and, in autonomic, and heart control, without EEG alterations [14], such as was observed in this study.

A way to test DES is the ESS. In this study, we compared scores of the six groups, and found not significant differences in them, such as was observed by other researchers [15,16]. However, we observed that the group of PLMs/severe OSAHS presented a higher score of ESS than the other groups, suggesting the additive effect of both diseases (PLMs and OSAHS) in SA alteration and their daytime effects. Alterations were more severe when apnea end was associated to limb movements, with an increase of heart rate (HR), when compared to respiratory events without HR increase, as observed previously by Yang et al. [17]. Cyclic changes in HR and Blood pressure (BP) are suggested that results from recurrent peripheral vasoconstriction commanded by the Autonomic nervous system (ANS). These facts could be responsible of the increased frequency of cardio-vascular diseases in patients with OSAHS [3,18], demanding the search of these events in patients with suspicion of PLMs and SBD in mandatory way. Identification of PLMs after respiratory events in patients with OSAHS must alert clinicians to a higher cardiovascular risk, as suggested by Manconi et al. [13]. However, in our study, we found no differences in HR among the six compared groups that could suggest the same quoted effect.

It is of interest, that males in the group with PLMs and all groups with OSAHS, had a major frequency of SA alterations. On the contrary, the group with PLMs, had higher frequency of female patients. These results, is in agreement in previous reports. Explanations why males had more SBD, is related to the alterations of a higher body weight, and body fat increasing, collapsing SAP. On the other hand, PLMs are more common in females [19].

Both, PLMs and SBD, had a higher frequency in older ages [20,21]. In our study, we observed an increase in mean age of patients with both disorders, and the higher frequency was noted in the group of patients with PLMs/severe OSAHS to the group of patients with PLMs. Patients with older age presented both disorders and a highest frequency of AHI. This fact is explained for presence of more frequent chronic-degenerative diseases in this age group, and the use of drugs for therapeutics, some of them could results in an increase of SMD, and SBD, and DES.

In children, Wang et al., explored the correlation between PLMs, AHI, apnea index (AI), hypopnea index (HI) and lowest oxygen saturation ($LSaO_2$) in children with SDB. They found that the difference of PLMI and PLMI-arousal between the children with OSAHS and children with other SDB types, PS, and upper airway resistance of sleep were not significant, the increased sleep stage 1 was significant, as being compared between the two groups, however, other sleep stages and sleep efficiency were not significantly different; the difference of HI, AI, AHI, arousals index (ArI) and $LSaO_2$ were not significant between the two groups; PLMI and PLMI-arousal were not correlated with AHI, HI, AI, AHI and $LSaO_2$, thus, they concluded that PLMS may be independent of SDB and PLMs had a little influence on sleep structure, in the same line as our results [22].

Frequently SMD and SBD can present in the same patient as a co-morbidity, disturbing SA that manifested as DES. Data from our observation indicated that both disorders must be treated one by one by clinicians, for a better result in SQ of patients with both sleep disorders.

4.3. Limitations of the study

Our study design was cross-sectional. In the future we must perform a prospective research. The number of studied patients was short in future studies we must study a larger sample of patients. However, our sample size was enough to disclose the complex relationships among patients with PLMs disorder and SBD, and patients with both disorders.

5. Conclusion

In conclusion, SMD and SBD, together resulted in more additive changes in PSG variables, than as a separately disorders, in a complex interaction. Research in these relations deserve future investigations.

References

[1] American Academy of Sleep Medicine. . International Classification of Sleep Disorders.Darien, IL: American Academy Of Sleep Medicine,; 2014.
[2] Ferri R. The time structure of leg movement activity during sleep: the theory behind the practice. Sleep Med 2012;13:433–41.
[3] Al-Alawi A, Mulgrew A, Tench E, Ryan F. Prevalence, risk factors and impact on daytime sleepiness and hypertension of periodic leg movements with arousals in patients with obstructive sleep apnea. J Clin Sleep Med 2006;2:281–7.
[4] Reyes-Trigueros S, Pineda-Cazares S, Poblano A, Saldaña-Aceves R, Bernal-Bermúdez R, Rodríguez-Piña JH. Comparison of oxygen saturation and Epworth sleepiness scale in patients with mild, moderate, and severe obstructive sleep apnea syndrome. ORL MEX 2015;60:169–74.
[5] J.M. Parish, V.K. Somers, Obstructive sleep apnea and cardiovascular disease, Mayo Clin Proc, 79, 2004, 1036 1046.
[6] Torre-Bouscoulet L, Vázquez-García JC, Muciño A, Márquez M, López MV, Montes de Oca M, Tálamo C, Valdivia G, Pertuze J, Menezes A, Pérez-Padilla R. PLATINO goup. Prevalence of sleep related symptoms in four Latinamerican cities. J Clin Sleep Med 2008;4:579–85.
[7] Exar EN, Collop NA. The association of upper airway resistance with periodic limb movements. Sleep 2001;24:188–92.
[8] Iriarte J, Alegre M, Irimia P, Urriza J, Artieda J. Clinical relevance of periodic limb movements during sleep in patients with obstructive sleep apnea. Rev Neurol 2000;30:101–4.

[9] Homan RW, Herman J, Purdy P. Cerebral location of international 10-20 system electrode placement.Boston: Little Brown & Co: Boston,; 1969. p. 421–38.
[10] Berry RB, Brooks R, Gamaldo CE, Harding SM, Marcus CL. Vaughn BV for the American Academy of Sleep Medicine. The AASM Manual for the Scoring of sleep and Associated Events: Rules, Terminology and Technical Specifications. Darien, IL: American Academy Of Sleep Medicine,; 2012.
[11] Jiménez-Correa U, Haro R, Poblano A, Arana-Lechuga Y, Terán G, González-Robles RO, Velázquez-Moctezuma J. Mexican version of the Epworth Sleepiness Scale. Open Sleep J 2009;2:6–10.
[12] Terzano MG, Parrino L, Rosa A, Palomba V, Smerieri A. CAP and arousals in the structural development of sleep: an integrative perspective. Sleep Med 2002;3:221–9.
[13] Manconi M, Zavalko I, Bassetti CL, Colamartino E, Pons M, Ferri R. Respiratory-related leg movements and their relationship with periodic leg movements during sleep. Sleep 2014;37:497–504.
[14] Bonsignore MR, Parati G, Insalaco G, Castinglioni P, Marrone O, Romano S, Salvaggio A, Mancia G, Bonsignore G. Baroreflex control of heart rate during sleep in severe obstructive sleep apnoea: effects of acute CPAP. Eur Respir J 2006;27:128–35.
[15] Jiménez-Correa U, Haro R, González-Robles RO, Velázquez-Moctezuma J. How is the Epworth Sleepiness Scale related with subjective sleep quality and polysomnographic features in patients with sleep-disordered breathing. Sleep Breath 2011;15:513–8.
[16] Chervin RD. Periodic leg movements and sleepiness in patients evaluated for sleep-disordered breathing. Am J Respir Crit Care Med 2001;164:1454–8.
[17] Yang CK, Jordan AS, White DP, Winkelman JW. Heart rate response to respiratory events with or without leg movements. Sleep 2006;29:553–6.
[18] Narkiewicz K, Somers VK. Sympathetic nerve activity in obstructive sleep apnoea. Acta Physiol Scand 2003;177:385–90.
[19] Eisensehr I, Ehrenberg BL, Noachtar S. Different sleep characteristics in restless legs syndrome and periodic limb movements disorders. Sleep Med 2003;4:147–52.
[20] Claman DM, Ewing SK, Redline S, Ancoli-Israel S, Cauley JA, Stone KL. Study of Osteoporotic Fractures Research Group. Periodic leg movements are associated with reduced sleep quality in older men. J Clin Sleep Med 2013;9:1109–17.
[21] Scofield H, Roth T, Drake C. Periodic limb movements during sleep: population prevalence, clinical correlates, and racial differences. Sleep 2008;31:1221–7.
[22] Huang ZY, Liu DB, Tan ZY, Zhong JW, Qiu SY, Yu J. Study on periodic limb movement during sleep in children with sleep-disordered breathing. Zhonghua Er Bi Yan Hou Tou Jing Wai KE ZA Zhi 2010;45(2):111–5.