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The role of mean inspiratory effort on daytime sleepiness

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The role of mean inspiratory effort on daytime sleepiness. Z. Pelin, D. Karadeniz, L. Öztürk, E. Gözükirmizi, H. Kaynak. ©ERS Journals Ltd 2003.

ABSTRACT: This study has investigated the role of average maximum inspiratory effort in excessive daytime sleepiness in patients with obstructive sleep apnoea syndrome (OSAS) and upper airway resistance syndrome (UARS).

Fifteen patients diagnosed with UARS and 32 patients with OSAS, with >5.5 h total sleep time (TST) during 8 h of nocturnal polygraphic recordings, were included in the study. Demographical data, polysomnographical data and data about daytime sleepiness, including Epworth sleepiness scale (ESS) and multiple sleep latency test (MSLT), were evaluated. In order to compute the average maximum inspiratory effort from oesophageal pressure (P_{oes}) measurements, maximum P_{oes} was obtained from 20 representative obstructive respiratory events (obstructive apnoeas, hypopnoeas or flow limitations) for each sleep stage in both supine and side positions. From P_{oes} measurements during sleep, the increase in P_{oes} (ΔP_{oes}) during respiratory events was also calculated.

The average maximum P_{oes}, ΔP_{oes}, respiratory disturbance index (RDI) and arousal index were significantly correlated with ESS in OSAS patients. In patients with UARS, the only significant correlation was obtained between average maximum P_{oes} and ESS. The MSLT score did not show any significant correlation with arousal index, number of stage variations, RDI, average P_{oes}, ΔP_{oes}, minimum oxygen saturation (S_{a,O_2}) and percentage of TST with an S_{a,O_2} <90% in both UARS and OSAS patients. The results of multiple regression analysis showed that average maximum P_{oes} correlates best with the variance in ESS for OSAS patients.

In conclusion, the data from this study indicate the possible important role of average inspiratory effort in determining subjective sleepiness in both obstructive sleep apnoea syndrome and upper airway resistance syndrome patients.

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Excessive daytime sleepiness (EDS) is one of the most prominent symptoms associated with obstructive upper airway disorders during sleep [1, 2]. As a consequence of EDS, significant deterioration is observed in daily performance of patients, with impairment in psychosocial and cognitive functions [3]. Besides affecting the quality of life, EDS also increases the risk of motor vehicle and industrial accidents [3, 4].

In obstructive sleep apnoea syndrome (OSAS), many hypotheses have been proposed to explain EDS. Different aspects of polysomnographical evaluations, such as changes in breathing (*i.e.* apnoea/hypopnoea [5–8] or hypoxaemia [7–9]), have been postulated as the main causes of EDS. In addition, reduction in the restorative nature of sleep by arousals [10–12], fragmentation of sleep [13, 14], a lack of slow-wave sleep [15] and a reduction in total sleep time (TST) [16], have all been suggested as possible causes of EDS.

Patients with upper airway resistance syndrome (UARS) also complain of daytime sleepiness [17, 18], like patients with OSAS. Nocturnal polygraphical recordings, however, indicate differences between these two groups. During apnoeic or hypopnoeic events, OSAS patients show a substantial decrease in arterial oxygen saturation (S_{a,O_2}). Conversely, in UARS, S_{a,O_2} may fluctuate somewhat, but it stays at ~90%; the abnormal events are short, involving one or two breaths and consist of flow limitation but no apnoea [17, 19]. Arousal reaction and consequent sleep fragmentation have been commonly thought to cause EDS in both syndromes [17, 20]. However, some studies performed in patients with OSAS failed to show a strong association between sleep fragmentation and daytime somnolence [21, 22]. Also in UARS, hypoxaemia, which was suggested to be an independent determinant of hypersomnolance in OSAS [7, 8], is an excluding factor contributing to daytime somnolence. Therefore, there are some questions about daytime sleepiness in patients with OSAS and UARS that remain answered. One of these questions is whether the degree of sleepiness is similar or not. If not, which variables, such as sleep structure, sleep fragmentation and respiratory variables, contribute the difference in sleepiness between UARS and OSAS. Another question is whether the amount of respiratory effort in UARS *versus* OSAS subjects could lead to differences in their sleepiness.

In one study, ZAMAGNI *et al.* [23] demonstrated that the degree of respiratory effort during obstructive apnoeas contributes to self-rated sleep propensity in patients with OSAS. In that study obstructive apnoeas selected only from nonrapid eye movement (NREM) sleep were evaluated. However, it was reported that among 34 patients with mild OSAS, the apnoea/hypopnoea index (AHI) during rapid eye movement (REM) sleep, but not the AHI for the entire night, was well correlated with the mean sleep latency on multiple sleep latency tests (MSLT) [24]. However, CHERVIN and ALDRICH [25] suggested that apnoeic events during REM and

NREM sleep probably contribute equally to sleepiness as measured by the MSLT [25]. Therefore, evaluating the effect of respiratory effort on sleepiness in different sleep stages might supply further information about daytime sleepiness in obstructive respiratory disorders.

In the present study, the effects of inspiratory effort on daytime sleepiness, with the inclusion of the influences of sleeping position and sleep stages, were investigated in both UARS and OSAS. Other demographical and polysomnographical variables were also evaluated. In a previous study, the relationship between AHI supine sleep and daytime sleepiness was documented by CHERVIN and ALDRICH [8]. However, the influence of sleeping position on the amount of respiratory effort in the context of daytime sleepiness has not been investigated before. Only sleep stage dependent changes in respiratory effort were reported by KRIEGER *et al.* [26]. They found that the respiratory effort was lower in REM than NREM sleep, but they did not establish a connection between this variability and EDS.

In this study, testing for associations between Epworth sleepiness scale (ESS)- and MSLT-defined sleepiness, and inspiratory effort and other variables, was reported in patients with UARS as well as OSAS.

Material and methods

Subject selection

From 150 consecutively selected patients, the clinical and polysomnographical data of 47 patients (11 females and 36 males) were evaluated. Inclusion criteria for the study included: 1) diagnosis of OSAS or UARS; and 2) >5.5 h of TST during 8 h polysomnographical recordings. Patients with restless leg syndrome and periodic leg movements during sleep were not included in the study. Fifteen patients were diagnosed as UARS with an AHI<10 and minimum Sa,O_2>90%. For the diagnosis of UARS, the patient also had to have complained about excessive daytime sleepiness and have an increased number of arousals associated with increased respiratory effort. The other 32 patients were evaluated as OSAS with AHI>10 and minimum Sa,O_2<90%. All patients underwent clinical interview before nocturnal polysomnography and these investigations were performed without any treatment.

Polysomnographical evaluations: sleep and respiratory variables

Nocturnal polygraphic recordings included the following variables: electroencephalogram (EEG) (C_3/A_2-C_4/A_1, according to the 10–20 international electrode placement system), electrooculogram, chin electromyogram and electrocardiogram. Respiration was analysed with a pneumotachograph attached to a face mask. Snoring was evaluated with a microphone that was placed above the larynx. Oesophageal pressure (*P*oes) was measured with a latex balloon placed in the lower third of the oesophagus, as described by BAYDUR *et al.* [27], connected to a pressure transducer and inflated with 1 mL of air. The saturation during sleep was measured continuously using finger oxymetry.

Nocturnal recordings were scored according to the standard criteria of RECHTSCHAFFEN and KALES [28], as epochs of 30 s, and the following sleep variables were calculated: TST, sleep efficiency index (TST/time in bed), sleep continuity index (TST/total sleep period), waketime after sleep onset, percentages of sleep stages, and awakening and arousal index. Awakening was defined as transition to awake state from any NREM or REM sleep stage for ⩾15 s and the awakening index was calculated as the number of awakenings per hour of the total sleep period.

Abnormal respiratory events were evaluated according to standard criteria of American Sleep Disorders Association (ASDA) [29]. An apnoea was defined as a cessation of airflow with a duration of ⩾10 s. A hypopnoea was defined as ⩾50% reduction in airflow relative to baseline, coupled with a desaturation of ⩾4%. Obstructive type apnoeas were differentiated from central and mixed apnoeas with *P*oes analysis. Flow limitations were differentiated from the other abnormal respiratory events as they were defined as episodes during which there was an increase of ⩾20% in peak-to-peak *P*oes amplitude, compared with baseline, lasting ⩾15 s, with a reduction in flow not >50% of baseline. These episodes were not accompanied by significant oxygen desaturation and resulted in awakening or arousal reactions and the breath following the awakening or arousal reaction showed an abrupt reduction in *P*oes (fig. 1). Baseline peak-to-peak *P*oes fluctuations were obtained during awake, unobstructed breathing. The AHI was calculated as the number of apnoeas and hypopnoeas per hour of sleep. However, respiratory disturbance index (RDI) was established as the number of all obstructive type respiratory events per hour of sleep including flow limitations. As an index of nocturnal Sa,O_2, the minimum Sa,O_2 level throughout the night was measured. For OSAS patients, percentage TST with an Sa,O_2 <90% was also calculated.

Arousals were determined according to ASDA criteria [30] and the arousal index was computed as the number of arousals per hour of sleep.

Assessment of daytime vigilance

Daytime sleepiness was assessed subjectively by ESS [31] and objectively by MSLT [32].

The Turkish version of ESS was administered by two technicians. In the current authors' laboratory there are rules for the administration of ESS that limit subjective evaluations

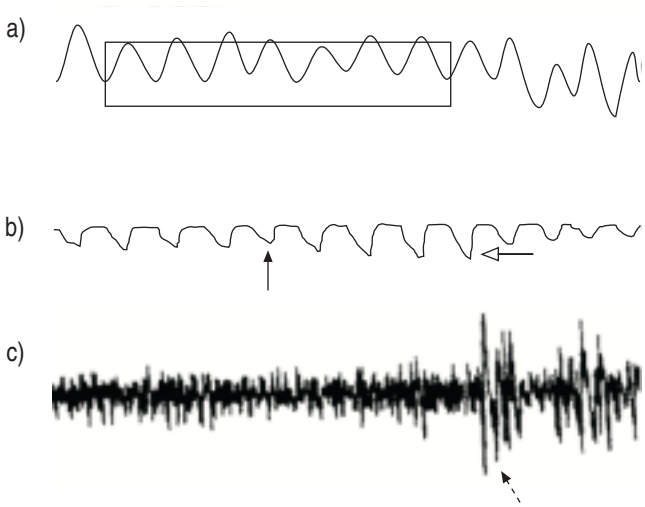

Fig. 1. – Oesophageal pressure (*P*oes) measurement for flow limitation (box). a) Flow, b) *P*oes and c) electroencephalogram. The minimum of the first three *P*oes where the crescendo pattern began was taken as minimum *P*oes (closed arrow; -6). The maximum of the last three *P*oes values just before the effort associated arousal (dashed arrow) was taken as maximum *P*oes (open arrow; 8).

of technicians. For the ESS, 2–10 was accepted as normal and >10 was an indicator of pathological degree of sleepiness [33].

The MSLT was performed in the sleep laboratory the day following the polysomnographical examinations [32]. The MSLT consisted of five naps scheduled at 10:00, 12:00, 14:00, 16:00 and 18:00 h. The mean sleep latency was calculated by averaging the individual latency scores of the five sleep latency tests. A mean latency to sleep onset of $\leqslant$5 min indicated severe sleepiness, while >10 min was taken as normal. The patient population with a mean sleep latency, in the range of 5–10 min, was classified as mild in sleepiness [32].

The cut-off points of excessive sleepiness for ESS (10 point) and MSLT (5 min) were not used for statistical analysis. They were only used for the evaluation of patients on an individual basis.

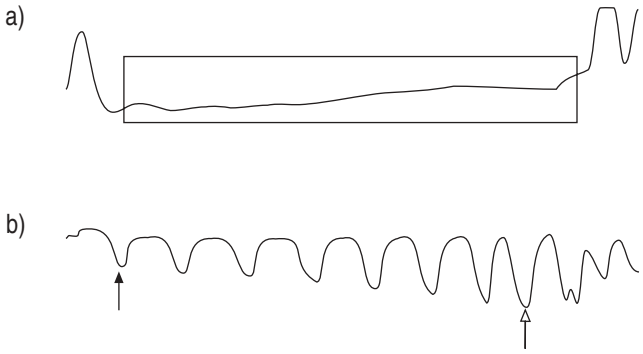

Fig. 2. – Oesophageal pressure (P_{oes}) measurement for obstructive apnoea. a) Flow and b) P_{oes}. The minimum of the first (closed arrow; 16) and the maximum of last three (open arrow; -42) P_{oes} were taken.

Assessment of respiratory efforts

Twenty representative obstructive respiratory events (obstructive apnoeas, hypopnoeas or flow limitations) were selected from the sleep stages (stages (st.) 1+2, 3+4) of NREM and REM sleep in both supine and side positions, and each respiratory event was evaluated to analyse inspiratory effort. Mixed and central apnoeas were not included in the analysis. As shown in figure 2, P_{oes} variations (from end-expiration to peak inspiration in the wave of P_{oes}) during the first three and the last three occluded inspiratory efforts within obstructive apnoeas were measured. The minimum value of the first three efforts was taken as the minimum P_{oes} and the maximum of the last three occluded efforts as the maximum P_{oes}. In order to analyse the inspiratory effort within the flow limitation episode, the P_{oes} value at end-expiration for each breath was measured. The maximum of the three occluded inspiratory efforts before effort-associated awakening or arousal reactions was assessed as the maximum P_{oes} (fig. 1). Although the crescendo pattern of inspiratory effort was not as brief as obstructive apnoeas, three inspiratory efforts were taken at the beginning of the episode that was $\geqslant$15 s before the awakening or arousal reaction, and the minimum value of these measurements was accepted as the minimum P_{oes}. The duration of each sleep stage in certain positions was also measured manually from recordings.

In the different sleep stages and positions, maximum P_{oes} was calculated by the average of 20 measured maximum P_{oes} values of abnormal obstructive respiratory events. The P_{oes} value for nocturnal polygraphic recording was calculated by using the following formula:

$$\begin{aligned}&\text{Average maximum } P_{oes} = (\text{side position } P_{oes(st.1+2)}\\&\times \text{time spent in side position}_{(st.1+2)}) + (\text{supine } P_{oes(st.1+2)}\\&\times \text{time spent in supine position}_{(st.1+2)}) + (\text{side position}\\&P_{oes(st.3+4)} \times \text{time spent in side position}_{(st.3+4)}) \qquad (1)\\&+ (\text{supine } P_{oes(st.3+4)} \times \text{time spent in supine position}_{(st.3+4)})\\&+ (\text{side position } P_{oes(REM)} \times \text{time spent in side position}_{(REM)})\\&+ (\text{supine } P_{oes(REM)} \times \text{time spent in supine position}_{(REM)})/\text{TST}\end{aligned}$$

The same formula was also used for computing the average minimum P_{oes} values. The difference between the average maximum and the minimum inspiratory effort was taken as a measurement of the overall increase in the inspiratory effort during obstructive respiratory event (ΔP_{oes}).

P_{oes} values were reported as absolute values to facilitate interpretation of the results. Therefore, higher P_{oes} reflected an increase in respiratory effort.

Statistical analysis

Results are presented as mean±SD. Sleep and respiratory parameters of patients diagnosed with OSAS and UARS were compared using the unpaired t-test.

For both UARS and OSAS patients, bivariate correlation analysis using Pearson′s correlation coefficient was performed, using the ESS and MSLT scores as dependent variables and variables associated with sleep structure, respiratory events, respiratory effort and severity of hypoxaemia as independent variables. The parameters that were significantly correlated and very close to significance were included in multiple regression analysis.

The backward method was used for multiple regression analysis, taking the ESS scores and mean sleep latency of MSLT as dependent variables to identify significant models with the probability of F to remove $p \leqslant 0.20$.

Statistical significance was accepted for a p-value of <0.05.

Results

The patient population consisted of UARS and OSAS patients. Ten of 15 patients with UARS and 26 of 32 patients with OSAS were male. There were no significant overall differences in age (45±9 *versus* 48±10) and body mass index (30.3±4.9 *versus* 31.3±4.2) between UARS and OSAS patients, respectively.

The descriptive measurements of nocturnal sleep and respiratory parameters of OSAS and UARS patients are presented in table 1. OSAS patients showed wide variability in severity of nocturnal hypoxaemia, with a minimum S_{a,O_2} ranging 49–87%, while a minimum S_{a,O_2} of 90% was used as a diagnostic criterion for UARS patients. Although there was a significant difference in percentage of NREM 1–2 between OSAS and UARS patients, no significant difference in REM and slow-wave sleep was found. Arousal index was significantly higher in OSAS compared to UARS patients, 32±12 and 64±14, respectively.

The ESS score showed variability, ranging 1–20, in patients with both OSAS and UARS. The mean sleepiness score of UARS patients was 8.1±3.6 (range 1–16), while the mean score of OSAS patients was 10.6±5.2 (range 3–20). There were 16 OSAS and three UARS patients with an ESS score >10, which was defined as the upper point of normal range of sleepiness [33]. The MSLT scores also showed a wide distribution, ranging 2.5–14 min (mean 7.0±3.3) in UARS patients and 1–10 min (mean 4.7±2.0) in OSAS patients. The pathological degree of sleepiness for the MSLT, which was defined as <5 min, was found in 22 OSAS and four UARS

Table 1. – Nocturnal sleep and respiratory parameters

	UARS	OSAS
Subjects n	15	32
Total sleep time min	381±29	411±39**
Stage 1–2 %	55±10	72±12***
Stage 3–4 %	16±6	12±6
NREM sleep %	11±5	8±4
WASO %	17.9±5.9*	12.5±7.4
Awake index	4.7±1.6	3.4±2.4
Arousal index	32±12	64±14***
AHI $n \cdot h^{-1}$	5.8±4.2	57.3±24.2***
RDI $n \cdot h^{-1}$	36.3±11.7	66.9±14.4***
Min. O_2	90.1±1.9	74.4±10.4***
%TST with O_2 <90%		27.9±24.4

UARS: upper airway resistance syndrome; OSAS: obstructive sleep apnoea syndrome; NREM: nonrapid eye movement; WASO: waketime after sleep onset; AHI: apnoea/hypopnoea index; RDI: respiratory disturbance index; Min.: minimum; O_2: oxygen; TST: total sleep time. *: p<0.05; **: p<0.01; ***: p<0.001.

patients. ESS and MSLT scores showed that OSAS patients were significantly sleepier than UARS patients.

The maximum *P*oes calculated in each sleep stage and position are presented in table 2. Measurements in stages 3–4 for 12 OSAS patients and in REM for three OSAS patients were not performed due to the absence of these sleep stages in the recordings. Also, in two UARS patients, *P*oes levels during slow-wave sleep could not be determined because of inadequate duration. These unobserved sleep stages in certain positions were not taken into consideration for the calculation of averaged maximum *P*oes. The maximum *P*oes values did not differ between supine and side positions within the same sleep stages in OSAS patients. There was only significant positional difference obtained in UARS patients during slow-wave sleep; maximum *P*oes during supine position was higher than side position (40.2±11.7 and 30.2±6.5, respectively; p<0.01).

The average maximum *P*oes showed a wide range of variability in UARS as well as in OSAS patients. The average maximum *P*oes was 27.7±8.3 (range 16–53 cmH_2O) and 44.9±13.7 (range 22.8–78.3 cmH_2O) in UARS and OSAS patients, respectively. Other analyses of *P*oes between the two groups of patients are shown in table 3.

The ESS and MSLT were not significantly correlated with each other in either UARS (r=-0.27, p=0.32) or OSAS patients (r=-0.32, p=0.07).

The results of bivariate correlation analysis for UARS and

Table 2. – The distribution of maximum oesophageal pressure (*P*oes) according to sleep stages and positions

	UARS	OSAS
Subjects n	15	32
Side position $P_{oes(st.1+2)}$	25.5±7.9	42.1±15.7***
Supine $P_{oes(st.1+2)}$	29.2±10.1	48.7±15.1***
Side position $P_{oes(st.3+4)}$	30.2±6.5	48.7±16.2***
Supine $P_{oes(st.3+4)}$	40.2±11.7#	47.3±14.4
Side position $P_{oes(REM)}$	19.2±3.7	30.7±9.4***
Supine $P_{oes(REM)}$	21.5±6.2	31.6±11.1*

UARS: upper airway resistance syndrome; OSAS: obstructive sleep apnoea syndrome; $P_{oes(st.1+2)}$: *P*oes in stages 1+2; $P_{oes(st.3+4)}$: *P*oes in stages 3+4; $P_{oes(REM)}$: *P*oes in rapid eye movement sleep. *: p<0.05; ***: p<0.001 for comparison between UARS and OSA patients; #: p<0.05 for comparison between supine and side position within the same sleep stage.

Table 3. – Analysis of oesophageal pressure (*P*oes) for whole polygraphic recordings

	UARS	OSAS
Subjects n	15	32
Average max. *P*oes cmH_2O	27.7±8.3	44.9±13.7***
Average min. *P*oes cmH_2O	10.9±1.9	16.6±7.6***
Δ*P*oes cmH_2O	19.7±7.4	28.5±10.1*

UARS: upper airway resistance syndrome; OSAS: obstructive sleep apnoea syndrome; max.: maximum; min.: minimum; Δ*P*oes: max. *P*oes–min. *P*oes. *: p<0.05; ***: p<0.001.

OSAS are presented in table 4. In patients with UARS, the only significant correlation was obtained with average *P*oes and Epworth score (r=0.48, p=0.035). ESS score was found to be positively correlated with arousal index, number of stage variations, RDI, average *P*oes, Δ*P*oes and percentage of TST with an Sa,O_2 <90% in OSAS patients (table 4). There was no significant correlation for the MSLT scores in either UARS or OSAS patients.

In OSAS patients, the multiple regression analysis, using the backward method, was performed to more clearly define the relationship of these correlated variables with the Epworth score. The selected model included number of stage variations and average *P*oes. The multiple correlation coefficient (R=0.51) was statistically significant (F=5.17, df=2, p=0.012). The only significant beta weight was for average *P*oes (β=0.165, SE of β=0.06, p=0.01).

Discussion

Excessive daytime sleepiness is a common complaint among patients with OSAS [1, 2]. The association between daytime sleepiness and various respiratory and/or sleep-related factors has been investigated for many years. Among these factors, the most apparent association has been established with AHI [5–8], hypoxaemia severity [7–9] and sleep

Table 4. – Correlation coefficients and their significance for Epworth and multiple sleep latency test (MSLT) scores in upper airway resistance syndrome (UARS) and obstructive sleep apnoea syndrome (OSAS) patients

	UARS		OSAS	
	r	p-value	r	p-value
Epworth score				
Arousal index	0.20	0.24	0.31	0.04
RDI	0.20	0.24	0.33	0.03
Average *P*oes	0.48	0.03	0.44	0.01
Δ*P*oes	0.31	0.12	0.34	0.02
Stage variations n	-0.19	0.47	0.26	0.07
Min. O_2 %	-0.28	0.15	-0.18	0.15
%TST with O_2 <90%			0.26	0.07
MSLT score				
Arousal index	-0.26	0.46	-0.16	0.18
RDI	-0.01	0.49	-0.14	0.22
Average *P*oes	-0.35	0.10	0.02	0.45
Δ*P*oes	-0.22	0.21	0.06	0.36
Stage variations n	0.28	0.16	0.13	0.23
Min. O_2 %	0.38	0.09	0.23	0.1
% TST with O_2 <90%			-0.13	0.24

RDI: respiratory disturbance index; *P*oes: oesophageal pressure; Min.: minimum; O_2: oxygen; TST: total sleep time.

fragmentation [10–14]. The novelty in the current data is the demonstration that the average inspiratory effort during obstructive respiratory events, calculated with respect to sleep stages and positions, contributes to self-rated sleep propensity in both UARS and OSAS patients.

The AHI, which is a commonly accepted indicator of disease severity, did not show a persistent relationship with daytime sleepiness. Although it has been suggested that there is a significant association between sleepiness and RDI [6–8, 34], in a study of Wisconsin state employees [35], 9% of females and 24% of males had an RDI of >5, while only 2% of females and 4% of males reported daytime sleepiness. A higher percentage of reported sleepiness was found even in patients with an RDI of <5 [34, 35]. In this study, RDI was significantly higher in patients with OSAS than with UARS. Furthermore, OSAS patients were sleepier than patients with UARS in both the subjective and objective evaluation of sleepiness. This finding might be explained by the findings of previous studies, which showed a linear association between sleepiness and RDI [33, 34]. However, a very weak correlation between RDI and ESS score in OSAS patients, and no correlation with ESS in UARS and with MSLT in both UARS and OSAS patients did not support this explanation in the current study.

Another possible explanation of the difference in sleepiness between UARS and OSAS patients is the contribution of hypoxaemia to the sleepiness of OSAS patients. Several investigators [36–38] have suggested that nocturnal hypoxaemia may be the primary cause of hypersomnolance in OSAS patients. In two separate reports, MENDELSON [36, 37] has shown that measures of oxyhaemoglobin desaturation were the most significant predictors of daytime sleepiness as measured by MSLT. In support of these findings, there are further studies suggesting the importance of nocturnal hypoxaemia as an independent contributor to sleepiness in OSAS patients [7, 8]. Interestingly, no correlation was found between measures of hypoxaemia severity and MSLT score in OSAS patients, which might be due to the difference in measure of hypoxaemia. PUNJABL *et al.* [7] categorised the severity of oxyhaemoglobin desaturation as ⩽5%, 5.1–10%, 10.1–15% and >15%, and found an inverse relationship between the degree of drop in saturation and hypersomnolance. However, CHERVIN and ALDRICH [8] suggested that minimum Sa,O_2 had an independent contribution to sleepiness in OSAS patients. However, minimum Sa,O_2 as a measure of hypoxaemia severity in the present study did not show any significant association between ESS score and MSLT. The only significant finding was the correlation between percentage of TST with an Sa,O_2 <90% and ESS in OSAS patients. The current authors believe that the effect of hypoxaemia on sleepiness deserves further investigation, but it does not seem to be an independent contributor to sleepiness in sleep disordered breathing if UARS is thought of as a physiological continuum between primary snoring and OSAS [39].

The average inspiratory effort, which was found as an explanatory variable to sleepiness in patients with UARS as well as OSAS, might be another confounding factor making OSAS patients more sleepy than patients with UARS. In this study, it was found that OSAS patients had more inspiratory effort throughout the night than the UARS patients. This finding could be accepted as one of the explanations of the difference in sleepiness between the two groups.

This explanation would take into account the most currently accepted explanation of daytime sleepiness in patients with UARS as well as OSAS, which relates daytime sleepiness to the consequences of abnormal respiratory events on sleep structure, causing arousal reactions and sleep fragmentation [10–12,14]. However, BERG *et al.* [40] reported that nonapnoeic snorers complaining of excessive daytime sleepiness have similar total numbers of arousal to asymptomatic controls. It was also suggested that this difference in daytime symptom is created by the type of arousals (pure EEG *versus* respiratory). ROEHRS *et al.* [13] also found a relationship between respiratory arousal index and daytime sleepiness. It has also been suggested that an increased effort of breathing is a more important stimuli for arousal than either hypercarbia or hypoxia [41]. If daytime sleepiness was affected by arousals, especially respiratory arousals, there might be other determining factors identifying the arousal as a respiratory outcome. Therefore, inspiratory effort might be one of the designating factors for arousals.

The lack of correlation between arousal index and any sleepiness index in patients with UARS and MSLT of OSAS patients was surprising. This may be due to the monitoring technique used or insufficiency of ASDA criteria for designating arousals rather than the actual absence of electrocortical activation. In the current study, central electrodes were used for EEG recordings and frontal electrodes were used to improve the detection of respiratory-related arousal reactions [42]. This might be one explanation for the failure to note visible arousal reactions in this study. Conversely, it has been proposed that there are some microarousals [43] and non-EEG indices of arousal-like autonomic activation (*i.e.* changes in blood pressure and heart rate) [14, 43], and increasing the number of these type of arousals has been shown to impair daytime functions in normal subjects [15] and OSAS patients [14, 43]. As a result it can be considered that detection of arousals according to ASDA criteria, as well as other parameters, would supply better information about the effects of arousals on daytime sleepiness.

In this study, another point to be discussed is the evaluation of arousal reactions relating to lower leg movements. MENDELSON [44] demonstrated that the index of periodic limb movement (PLM) with movement arousals was not different in patients with and without excessive daytime sleepiness. In addition, COLEMAN *et al.* [45] reported that there was no correlation between PLM index and MSLT in patients with primary insomnia and PLM during sleep (PLMS). Since the patients with restless leg syndrome and PLMS were excluded at the beginning of the study, it was expected that analysing the lower limb movement and associated movement arousals would not give any extra information about the sleepiness of patients with obstructive upper airway disorders during sleep.

AHI as a determinant of EDS has been investigated previously within the aspects of body position [8] and sleep stages [24, 25]. As a possible determinant of subjective sleepiness, inspiratory effort has been implicated by ZAMAGNI *et al.* [23], who evaluated obstructive apnoeas during NREM sleep. However, evaluation of respiratory effort considering body position and sleep stages has not been performed previously. In the current study, inspiratory effort for all obstructive respiratory events, including flow limitations in all sleep stages and in different positions, were evaluated.

CHERVIN and ALDRICH [8] suggested that excessive daytime sleepiness was better explained if sleeping position, type and character of abnormal respiratory event were taken into consideration during the evaluation of apnoeas and hypopnoeas. In that study, it was reported that the rate of apnoeic events in the supine position correlated better with daytime sleepiness. In this study, no position-dependent change in respiratory effort was found within the same sleep stage, except slow-wave sleep of UARS patients. The findings indicate that respiratory effort in both the supine and nonsupine positions probably contribute equally to the role of respiratory effort on daytime sleepiness. Moreover, the importance of apnoeas and hypopnoeas during different sleep stages, either REM sleep alone [24] or REM sleep as well as

NREM sleep [25], on the determination of daytime sleepiness, suggests a role for sleep stages in sleepiness. The authors found that inspiratory effort was lower in REM sleep than NREM sleep in patients with both UARS and OSAS. This conclusion is similar to previous findings [26]. The authors consider that evaluation of inspiratory effort in such large aspects, including body position and sleep stages, supply enlarged vision to the evaluation of sleepiness in sleep disordered breathing. The significant correlation between average inspiratory effort and ESS in patients with UARS also supported its important role in daytime sleepiness.

Some limitations of using *P*oes should be considered. Analysing the representative 20 obstructive respiratory events for each sleep stage and position totalled 80–120 respiratory events for each patient. This selection and positional differences between patients may have created variability in mean inspiratory effort. Therefore, using this formula in a study over consecutive nights and using a randomised selection of abnormal respiratory events may provide more information about the validity of this formula.

A possible explanation of the result of the current study is that inspiratory effort itself may increase sleepiness by way of energy expenditure throughout the night. The level of daytime sleepiness was described by JOHNS [46, 47] as a function of the total sleep drive to the total wake drive with which it competes, throughout the 24-h sleep/wake cycle. According to this theory, the majority of these drives are under the influence of the central nervous system. However, some behavioural and physical conditions, such as posture, feelings, mental and physical activity, have a role, especially on wake drive. Inspiratory effort, creating energy expenditure throughout the night, might be considered to affect the balance between sleep and wake drive in patients with UARS or OSAS.

In contrast with the Epworth score, any parameter showed significant correlation with MSLT scores in both UARS and OSAS patients. The lack of association between MSLT and any polysomnographic variables is also supported by other studies in which such associations are absent [48], ambiguous [20] or weak [13, 49]. The authors also failed to find a significant correlation between ESS and MSLT scores. Similarly, many investigators have reported poor or no association between sleep latency of MSLT and ESS and other subjective tests, such as Stanford sleepiness scale [50, 51]. A possible explanation might be that subjective and objective tests evaluate different aspects of sleepiness. In fact MSLT measures the speed with which a sleep episode occurs under standardised laboratory conditions, whereas ESS evaluates the frequency of unwanted sleep episodes under naturalistic conditions of daily life [52]. Under this definition, the term "average sleep propensity" might be more preferable for the parameter that ESS measures, as suggested by JOHNS [47].

In conclusion, by taking into consideration the effect of sleep stages and body position, this study provides new evidence for average inspiratory effort as a contributing factor to the self-rated sleep propensity in patients with upper airway resistance syndrome as well as obstructive sleep apnoea syndrome. Finally, measuring sleepiness with a more reliable test may provide better information for understanding the relationship between respiratory effort and daytime sleepiness in obstructive breathing disorders during sleep.

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