Body position and breathing abnormalities during sleep: a systematic study

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REZUMAT

Poziția corpului și anomaliile din timpul somnului: un studiu sistematic

Introducere: *Studiile existente privind influența poziției corpului asupra respirației nocturne s-au limitat la comparația dintre decubitul lateral și poziția dorsală.* ***Obiectivul*** *prezentului studiu a fost evaluarea sistematică a influenței poziției corpului asupra respirației nocturne la 105 pacienți cu sindrom de apnee hipopnee de somn (SAHS).* ***Material și metodă:*** *Toți pacienții incluși au avut un indice de apnee și hipopnee > 10/h, pe baza unei polisomnografii realizate în laboratorul de somnologie. Un senzor plasat la nivelul toracelui a permis detectarea a nouă poziții corporale disticte: dorsală (S), dorso-laterală dreaptă (SR), laterală dreaptă (R), ventro-laterală dreaptă (PR), ventrală (P), ventro-laterală stângă (PL), laterală stângă (L), dorso-laterală stângă (SL), semișezând (UP). Variabilele respiratorii (numărul de apnee obstructive, centrale și mixte, numărul de hipopnee și numărul de desaturări exprimate ca index pe oră din timpul total de somn) au fost evaluate în funcție de poziția corpului, folosind metoda non-parametrică Kruskal-Wallis H. Studiul comparativ a fost realizat utilizând testele Mann-Whitney U.* ***Rezultate:*** *45% din timpul total de somn a fost petrecut în poziția dorsală pentru pacienții incluși. Un efect semnificativ statistic al poziției corpului a fost documentat pentru toate variabilele respiratorii. Parametrii respiratori studiați s-au ameliorat în poziție dorso-laterală dreaptă și stângă în comparație cu poziția dorsală și în poziție ventro-laterală dreaptă și stângă în raport cu poziția laterală dreaptă, respectiv poziția laterală stângă. Toate variabilele respiratorii s-au îmbunătățit treptat prin trecerea din poziția dorsală a corpului în poziție ventrală.* ***Concluzii:*** *Un senzor capabil să detecteze nouă poziții ale corpului poate fi util în laboratorul de somnologie. Utilizând acest senzor, am constatat că la pacienții cu SAHS variabilele respiratorii nocturne se ameliorează continuu la trecerea de la poziția dorsală la poziția ventrală.*

Cuvinte-cheie: *poziția corpului, sindrom de apnee-hipopnee de somn, polisomnografie*

ABSTRACT

Background: *Until now, studies about body position and nocturnal breathing abnormalities have been restricted to comparing supine versus lateral positions.* ***Objectives:*** *In this retrospective study, we systematically evaluated the effect of body position on nocturnal breathing in 105 patients with a sleep apnea hypopnea syndrome (SAHS).* ***Methods:*** *All the patients had an apnea hypopnea index > 10/h, as judged from polysomnography performed in the sleep laboratory. A thoracic sensor allowed to detect nine distinct body positions: supine (S), supine right (SR), right (R), prone right (PR), prone (P), prone left (PL), left (L), supine left (SL) and sitting upward (UP). Respiratory variables (number of obstructive, central and mixed apneas, of hypopneas and of desaturations, all expressed as an index per hour of total sleep time) were evaluated versus the body positions, using the non-parametric Kruskal-Wallis H method. Pairwise comparisons were performed using Mann-Whitney U tests.* ***Results:*** *Most of the total sleep time (45%) was spent supine. A significant effect of body position was found for all the respiratory variables. Breathing was better in the intermediate SR and SL positions than S, and also better in PR and PL positions than, respectively, R and L. All the respiratory variables gradually improved when gradualling moving from the S to the P position.* ***Conclusions:*** *A nine position sensor, able to define intermediate positions in addition to the basic cardinal positions, is useful in the sleep laboratory. Using such a sensor, we found in SAHS patients that nocturnal breathing improves as a continuum from the S to the P position.*

Keywords: *body position, sleep apnea hypopnea syndrome, polysomnography*

Introduction

It is known that body position influences respiratory mechanics and breathing patterns during sleep. In a pioneer polygraphic study, Gastaut et al. described in 1966 the aggravating effect of the supine position, as well as the improvement induced by the adoption of the prone posture, in a Pickwickian patient [1].

A review of the literature regarding the influence of body position on respiratory events shows that there has been interest mostly in the effect of body position in patients with obstructive sleep apnea [2] and in postural variation in oropharyngeal [3], as well as in velopharyngeal [4] dimensions in such patients. Other topics have been the decrease in collapsibility of the pharynx linked to the lateral position in patients with obstructive sleep apnea [5] and the interaction between obesity and positional dependency in obstructive sleep apnea [6].

The rationale for performing this study was that, until now, studies about body position and nocturnal breathing abnormalities have been restricted to comparing supine versus lateral positions. We performed a retrospective study on patients diagnosed as having a sleep apnea hypopnea syndrome (SAHS) on basis of polysomnography in the sleep laboratory. Our objective was to systematically evaluate the effects of body position on sleep respiratory events (central, obstructive and mixed apneas, hypopneas and oxygen desaturations) using a body position sensor able to classify body position in nine distinct categories: supine, supine right, right, prone right, prone, prone left, left, supine left and sitting upward. Additionally, we

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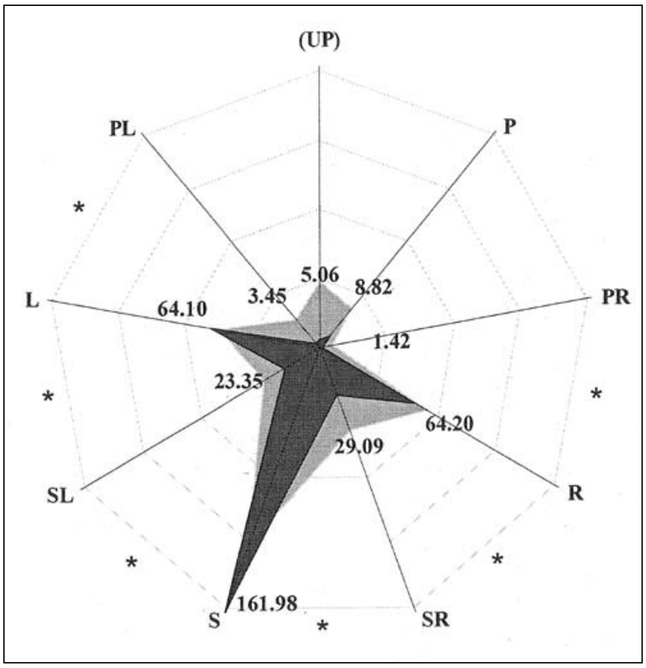
Figure 1. Time spent in each position. Values indicate the amount of sleep time (in minutes) spent in each position. The dark grey areas represent the mean time spent in each position and light grey areas represent the standard deviations. Asterisks denote statistical significant differences between adjacent body positions after Bonferroni correction (p<.006). L=left, P=prone, PL=prone-left, PR=prone-right, R=right, S=supine, SL=supine left, SR=supine right and UP=upward position



aimed to evaluate the usefulness of using intermediate positions in the study of the influence of body posture on respiratory variables.

Patients and Methods

Study design

This retrospective study, which was approved by the Institutional Review Board of the CHU Brugmann, included 105 patients (73 males and 32 females; mean (SD) age 54 (10) yr; mean BMI 30.8 (6.2)) admitted to the CHU Brugmann Sleep Unit between 1 October 2006 and 31 May 2007. All the patients were selected on basis of an apnea hypopnea index (AHI) >10/h. They presented with snoring, apneas witnessed by their spouse, morning fatigue and/or excessive daytime sleepiness. They were referred by pneumologists, oto-rhino-laringologists, psychiatrists, general physicians or were self-referred.

All participants admitted to the sleep unit were recorded without habituation and were requested to be free of psychotropic medications for at least 15 days prior to polysomnography.

Methods: Polysomnography

Participants were prepared for the recordings between 10:00 and 11:00 PM and allowed to retire when they wished. Morning arousal was spontaneous. Polysomnography included three electroencephalograms recorded from the Fp2-Al, C4-A1 and O2-A1 sites, two electrooculograms, submental and bilateral anterior tibial electromyograms. Oral and nasal airflow were recorded by thermistor airflow sensors (Respironics, Murrysville, PA, USA), respiratory effort was measured by thoracic and abdominal belts (Pro-Tech CT2TM, Mukilteo, WA, USA). Oxygen saturation was monitored by photosensitive finger-oxymetry (Flexi-Form II 7000A Nonin Medical, Minneapolis, MN, USA). Body position was encoded in nine categories: supine (S), supine right (SR), right (R), prone right (PR), prone (P), prone left (PL), left (L), supine left (SL) and sitting upward (UP) as detected by the sensor 86410 included in the Alice 4 system, coupled with a software able to detect body position angular changes of 45° (Respironics, Murrysville, PA, USA).

Recordings were randomly analyzed by one of two well-trained technicians, on a 21-inch screen displaying 30 second polysomnograph epochs. Standardized criteria were used for sleep-stage scoring [7]. Respiratory events were reviewed visually by the technicians. Inter-rater reliability (kappa) exceeds 0.89 for all variables in our sleep unit [8].

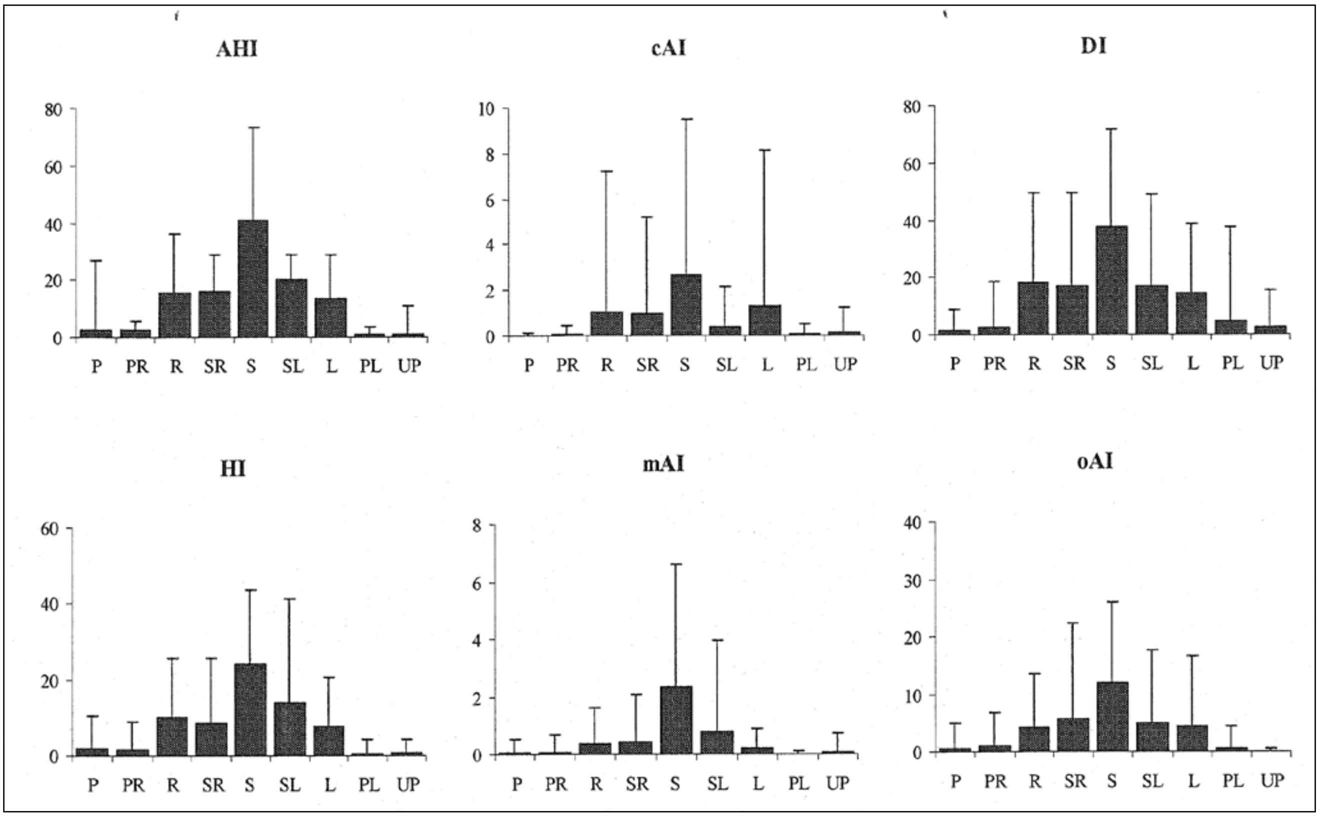
Sleep onset latency was defined as the time between lights out and the first period of stage 2. Sleep efficiency (SE) was defined by the total sleep time (TST)/time in bed (TIB) ratio. Non-rapid eye movement sleep (NREMS) included sleep stages 1 to 4. Rapid eye movement sleep (REMS) latency was defined as the time between the first epoch of stage 2 and the

Table I. Respiratory and sleep variables in 105 patients with sleep apnea hypopnea syndrome

		Mean	SD
Respiratory variables	AHI (h-1)	29.7	15.3
	oAI (h-1)	8.6	11.1
	cAI (h-1)	1.9	5.7
	mAI (h-1)	1.5	2.5
	HI (h-1)	17.8	13.1
	DI (h-1)	27.6	26.2
Sleep variables	Arousal Index (h-1)	38.6	16.7
	REM latency (min)	145	102
	REMS (min)	47	39
	NREMS (min)	316	96
	SWS (min)	59	56
	TST (min)	361	99
	SE (%)	70.9	16.8

AHI= apnea-hypopnea index; oAI=obstructive apnea index; cAI=central apnea index; mAI=mixed apnea index; HI=hypopnea index; DI=desaturation index; REMS= rapid eye movement sleep; NREMS= non-rapid eye movement sleep stages one to four; SWS=slow wave sleep; TST=total sleep time; SE=sleep efficiency

Figure 2. Respiratory variables by body posture. Dark grey vertical bars represent the mean respiratory variables for each position. Horizontal bars represent standard deviations



first of REMS. Light sleep was the sum of stages 1 and 2, slow wave sleep (SWS) was the sum of stages 3 and 4.

An episode of apnea was defined as cessation or more than 80% reduction in airflow amplitude for at least 10 seconds during sleep [9]. Apnea is classified as obstructive, central or mixed on the basis of presence or absence of respiratory effort [10]. The event is obstructive if during apnea there is effort to breathe, central if during apnea there is no effort to breathe; the event is mixed if the apnea begins as a central apnea, but towards the end there is effort to breathe without airflow [9]. A consensus conference (Chicago criteria) provided a definition of hypopnea as including one of three features: substantial reduction in airflow amplitude (>50%), moderate reduction in airflow (<50%) associated with an oxygen desaturation of >3% or moderate reduction in airflow (<50%) with an electroencephalographic evidence of arousal [11]. The apnea-hypopnea index (AHI) is defined as the total number of apneas and hypopneas divided by the TST [10]. Similarly, the obstructive apnea index (oAI), the central apnea index (cAI), the mixed apnea index (mAI), the hypopnea index (HI) and the desaturation index (DI) are defined as the total number, respectively of obstructive apneas, central apneas, mixed apneas, hypopneas and desaturations divided by the TST.

Statistical analysis

Respiratory variables were controlled for total sleep time by converting them to posture-dependent indices. These indices express the ratio of respiratory events in a specific posture by the time spent in that posture. All variables were

Table II. Pairwise comparisons between adjacent body positions. Values represent the Mann-Whitney U Z-statistic. Flagged (*) values are significant after Bonferroni correction (p<.001)

Posture comparison	Respiratory variables					
	AHI	cAI	DI	HI	mAI	oAI
P - PL	-2.26	-0.01	-1.68	-2.4	-0.48	-0.7
P - PR	-1.6	-0.01	-1.69	-1.42	-0.44	-0.3
R - PR	-8.26*	-4.84*	-7.94*	-8.24*	-4.14*	-5.87*
R - SR	-1.85	-0.89	-1.41	-2.64	-1.55	-1.23
L - PL	-9.29*	-4.97*	-8.95*	-8.54*	-3.46*	-5.71*
L - SL	-0.91	-2.05	-2.15	-0.67	-0.05	-0.27
S - SR	-7.37*	-5.99*	-6.48*	-7.65*	-7.13*	-7.55*
S - SL	-6.52*	-7.01*	-6.52*	-6.42*	-6.57*	-7.08*

AHI=apnea-hypopnea index; cAI=central apnea index; DI=desaturation index; HI=hypopnea index; mAI=mixed apnea index; oAI=obstructive apnea index; P-PL=prone-prone left; P-PR=prone-prone right; R-PR=right-prone right; R-SR=right-supine right; L-PL=left-prone left; L-SL=left-supine left; S-SR=supine-supine right; S-SL=supine-supine left

Table III. Parameter estimates from bi- and multinomial logistic regressions. For the multinomial logistic regressions the reference category is the group of patients with a mild expression of the variable

Variable	Parameter	Category	β	SE	Wald	p	Exp(β)
cAI	**S**	**-**	**.004**	**.002**	**4.41**	**< .05**	**1.004**
mAI	**S**	**-**	**.006**	**.002**	**5.56**	**< .05**	**1.006**
	R	**-**	**-1.344**	**.574**	**5.49**	**< .05**	**.261**
AHI	**R**	**moderate**	**1.57**	**.571**	**7.53**	**< .01**	**4.80**
oAI	**S**	**severe**	**.008**	**.003**	**5.94**	**< .05**	**1.008**
HI	**R**	**moderate**	**1.72**	**.53**	**10.36**	**< .001**	**5.56**
	UP	**moderate**	**-1.50**	**.67**	**4.98**	**< .05**	**.223**

checked for normality using Kolmogorov-Smirnov tests and QQ plots. All variables showed severe deviations from normality, except for age and body mass index (BMI). The effects of sex, age and BMI on sleep posture were investigated using binomial logistic and ordinary least squares regression analyses. The overall comparison of respiratory indices between sleep postures was performed using non-parametric testing (Kruskall-Wallis H) due to severe violations of the equality of variances assumption for parametrical testing. Post-hoc pairwise comparisons were performed using Mann-Whitney U tests. Bonferroni correction for multiple comparisons was used to minimize capitalization on chance. In order to predict respiratory variables by the proportion of time spent in different postures, mutlinomial logistic regressions were used. Non-normally distributed variables were transformed in either binary or categorical variables. Due to severe deviations from normality, the mAI and the cAI were converted in binary variables with "1" representing the occurrence of the respective apnea events and "0", non-occurrence. For this analysis, the AHI, the oAI and the HI were categorized as "mild" (< 15 events/h), "moderate" (>15 and <30 events/h) and "severe" (>30 events/h). The positional variables, except for the index representing the time spent in supine position, were transformed in binary variables where the occurrence of sleep in a specific position is represented by "1" and "0" for non-occurrence. All statistical analyses were performed using SPSS 16.0 (SPSS Inc., 2007).

Results

The time spent in each position, averaged over participants, is shown in Figure 1. Most of the time is spent in supine (45%) and, to a lower extent, in left (18%) and right (18%) positions. The time spent in intermediate supine position differs significantly from the supine, left and right positions; S-SR: Z=-9.34, p<.001, R-SR: Z=-4.05, p<.001, S-SL: Z=-9.74, p<.001 and L-SL: Z=-5.40, p<.001. The time spent in prone-lateral positions differ significantly from the lateral positions (R-PR: Z=-9.87, p<.001 and L-PL: Z=-10.15, p<.001), but not from the prone position (P-PR: Z=-2.0l, p=.044 and P-PL: Z=-l.55, p=.l22).

Table I further summarizes respiratory and sleep descriptive values. There are no effects of age and BMI on body position [respectively F(9,95)=1.301, p=.247 and F(9,95)=1.638, p=.l15]. Despite significant model fit tests [x2(9)=21.210, p<.05], none of the posture-related variables yield significant parameter estimates in predicting gender differences. Therefore, sex, age and BMI can be excluded for further analysis.

For the purpose of evaluating the usefulness of using intermediate positions in the study of body posture on respiratory variables, we compare the mean respiratory indices from four cardinal postures (S, L, R, P) with the intermediate positions (SR, SL, PR, PL). Non-parametric omnibus tests reveal significant effects of body position for all respiratory indices (AHI: $\chi^2(8)=375.20, p<.001$; oAI: $\chi^2(8)=323.45$, p<.001; cAI: $\chi^2(8)=242.36$, p<.001; mAI: $\chi^2(8)=243.49$, p<.001; HI: $\chi^2(8)=361.06$, p<.001 and DI: $\chi^2(8)=348.36$, p<.001). The effect of body position on the different respiratory variables is illustrated in Figure 2.

To locate specific differences in respiratory indices between different body postures, pairwise comparisons were performed (see Table II). As apparent from Figure 2 and Table II, all respiratory indices in supine position are significantly larger than the indices in intermediate positions (SR and SL). However, for none of the respiratory indices, intermediate supine-lateral positions differ significantly from the respective lateral position (R and L). The opposite pattern is observed for respiratory indices in prone position. There are no significant differences between indices in prone posture (P) and intermediate prone-lateral postures (PR and PL). On the other hand, indices from lateral postures (R and L) differ significantly from intermediate prone-lateral positions.

Significant associations between respiratory indices and body position were found for respiratory indices except for the desaturation index. Table III displays the parameters from the significant bi- and multinomial logistic regressions. Patients who spent more time in supine position are more likely to experience central apneas [$\chi^2(1)=4.98, p<.05$]. However, the odds of experiencing central apneas only increase by 1.004. Similar relations are found for the occurrence of mixed apneas, with the odds increasing only by 1.006 when time in supine position increases [$\chi^2(2)=9.05, p<.05$]. On the other hand, the odds of having mixed apneas decrease by 73.9% when sleep in the right lateral position is recorded. Significant associations between the severity of overall respiratory disturbance (AHI) and the occurrence of sleep in the lateral-right position has been found [$\chi^2(2)=9.03$, p<.05, AIC=23.44]. The odds of a moderately disturbed AHI in comparison to a milder form increase up to 4.80 when sleep in the right position occurs. Similarly, the odds of a moderately disturbed HI in comparison to a milder form increase by 5.56 [$\chi 2(4)= 14.318$, $p<.01$, AIC= 32.97]. On the other hand, having spent time in upward position decreases these odds by 77.7%. Finally, a significant association between time spent in supine position and obstructive apneas is observed [χ 2(2)=7.23, $p<.05$, AIC= 99.42], but the effect is rather small as the odds of a severe expression of the variable versus a mild one increase only by 1.008.

Discussion

The present study involving 105 SAHS patients studied in the sleep laboratory using a nine position thoracic sensor showed firstly that 45% of the sleep time was spent in supine position and, secondly, that respiratory variables were worst supine, and gradually improved when escaping from the supine position.

The predominance of the supine position may be a consequence of polysomnography itself. Indeed, the patient sleeping in the laboratory may adapt his or her position in order to not perturb the recordings. In 12 apneic patients, the time spent supine was found to be 56% greater during a night with polysomnography than during a night without sleep recordings [12]. During unattended home monitoring, the time spent supine is also shorter than during formal polysomnography at the Sleep laboratory [13]. Conversely, some amount of time in the supine position is desirable, as some patients show apneas solely in this position [2]. As a consequence, current guidelines about polysomnography state that sufficient sleep time in the supine position is necessary to avoid an inaccurate diagnosis [14].

A worsening effect of the supine position on nocturnal breathing in SAHS patients was not an unexpected finding. Indeed, the effect of gravity on the upper airway when adopting the supine posture has been studied in such patients, mostly in the awake state. The lateral, but not the anterioposterior, dimensions of the upper airway, assessed via fast computed tomography scanning, were found to decrease when SAHS patients adopt the supine position [15]. In a more recent study based on digitized cephalograms, the velopharynx was identified as the most changeable site in response to an alteration in body position [4]. All previous studies have focused on the so-called cardinal positions (supine, right, prone, left, sitting up). The originality of the present study is that we used a nine position sensor, also assessing intermediate positions (supine right, prone right, prone left and supine left). Using this sensor, we found that the respiratory variables in the supine right and supine left positions were significantly better than supine and that the values measured in the prone right and prone left positions were significantly better than, respectively, right and left.

In an early study published in 1984, Cartwright proposed to define "positional" apneic patients as those having at least twice as many apneas during sleep in the supine position as in the lateral position [2]. Since then, studies have focused on the distinction between positional and non-positional patients and most authors have found that more than half of the SAHS patients are positional [14]. Another originality of this study is that we did not aim to make this distinction. Indeed, we think that the categorization of patients into "positional" or "non-positional" on basis of a conventional sensor may be biased, as periods of the night spent in a given intermediate position are falsely detected as spent in one of the two adjacent cardinal positions. Rather than using an arbitrary definition for positional dependency, we performed an analysis on the respiratory variables versus the nine detected positions in the whole population. So doing, we were able to show a gradual worsening of all the respiratory variables, when gradually moving from the prone to the supine position.

The present study has several limitations. Firstly, characterizing body position using a single sensor at the thoracic level may be a suboptimal method. An additional sensor, assessing head and neck position, would yield useful information [14]. Indeed, head extension has been found to significantly decrease upper airway collapsibility, at least during pharmacological sedation in normal subjects [16]. Secondly, we did not study healthy subjects as a control group. To assess body position during sleep in normals would allow to assess to what extent the distribution of positions during sleep characterizes or not patients with SAHS. Thirdly, we studied subjects with a mean profile of moderate SAHS (mean AHI 29.6/h) and our results may not be generalized to populations with more severe SAHS. Indeed, the AHI has been shown to have a threshold effect on positional dependency, patients with an AHI > 40/h being less likely to worsen in the supine position [17].

In conclusion, our data obtained in 105 SAHS patients suggest that a nine position thoracic sensor, able to define intermediate positions in addition to the basic cardinal positions, is useful in the sleep laboratory. Significant differences in respiratory variables were found between some intermediate positions and some cardinal positions, and studying those intermediate positions allowed to show that nocturnal breathing gradually improves when gradually escaping from the supine position.

Acknowledgements

The authors thank Mrs. F. Martinez Vadillo for secretarial assistance.

Conflict of interest statement

None of the authors has any financial or personal relationship with other people or organizations that could inappropriately influence or bias this work.

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