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OSAHS

Can sleeping position be correctly identified by OSAS studies?

Siamo capaci di identificare correttamente la posizione del sonno negli studi su OSAS?

Luca Cerritelli[1], Luigi Marco Stringa[1], Giulia Bianchi[1], Henry Zhang[2], Giovanni Cammaroto[3], Claudio Vicini[1,3], Stefano Pelucchi[1], Andrea Marco Minetti[4]

[1] Ear-Nose-Throat & Audiology Unit, University of Ferrara, Ferrara, Italy; [2] Department of Otolaryngology, Head and Neck, Royal London Hospital, London, UK; [3] Department of Head-Neck Surgery, Otolaryngology, Head-Neck and Oral Surgery Unit, Morgagni Pierantoni Hospital, Forlì, Italy; [4] ENT MD freelancer, doctoral school in OSAS-EOS DRS, Milan, Italy

SUMMARY

Objective. Positional Obstructive Sleep Apnoea Syndrome (POSAS) is a sub-type of Obstructive Sleep Apnoea Syndrome (OSAS) in which obstructive apnoeas occur mainly in the supine sleeping position. In clinical practice, information on sleep posture is generally gathered by polysomnographic exam (PSG). The current trend in positional therapies consists of position trainers which help to avoid the supine position. The aim of this study is to detect the reliability of different devices on assessing sleeping position, comparing the data with objective evaluation by an infra-red camera.

Methods. We compared the positional results of 4 healthy volunteers obtained from a type III PSG and with a neck-worn sleep position trainer (Night Shift - NS).

Results. Data showed that NS is a good tool to assess the position of the trunk, with high rate of agreement with PSG, but in some conditions there are limitations, especially in detecting the real head and neck position and low accordance between NS data and information recorded by infra-red camera.

Conclusions. Our study confirmed that more information about body position during sleep is needed, underling the necessity of developing new technologies that are able to better identify reciprocal body positions.

KEY WORDS: OSAS, POSAS, sleep position, obstruction, devices

RIASSUNTO

Obiettivo. *La sindrome delle apnee ostruttive notturne posizionali (POSAS) è un sottotipo della sindrome delle apnee ostruttive notturne (OSAS) nella quale le apnee si verificano prevalentemente in posizione supina. Nella pratica clinica, le informazioni sulla posizione nel sonno sono acquisite grazie a un polisonnigrafo (PSG). Attualmente le terapie posizionali utilizzano correttori di posizione che aiutano a evitare la posizione supina. L'obiettivo dello studio è quello di individuare la correlazione fra diversi rilevatori di posizione, confrontando i dati con una valutazione oggettiva fornita da una telecamera a infrarossi.*

Metodi. *Abbiamo confrontato i dati ottenuti da 4 volontari sani mediante un PSG di tipo III e un dispositivo di terapia posizionale applicato al collo (Night Shift - NS).*

Risultati. *I dati hanno mostrato che il NS è uno strumento efficace e altamente correlabile al PSG per valutare la posizione del tronco. Tuttavia i dati raccolti hanno evidenziato una bassa correlazione tra il NS e la telecamera a infrarossi per quanto concerne l'individuazione della reale posizione di testa e collo.*

Conclusioni. *Il nostro studio ha confermato la necessità di elaborare nuove tecnologie per ottenere ulteriori informazioni sulla posizione del corpo durante il sonno.*

PAROLE CHIAVE: *OSAS, POSAS, posizione nel sonno, ostruzione, dispositivi*

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Correspondence
Luca Cerritelli
Ear-Nose-Throat & Audiology Unit, University of Ferrara, via A. Moro 8, loc. Cona, 44124 Ferrara, Italy
E-mail luca.cerritelli.bo@gmail.com

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Introduction

Positional Obstructive Sleep Apnoea Syndrome (POSAS) is a sub-type of Obstructive Sleep Apnoea Syndrome (OSAS) in which obstructive apnoeas occur mainly in the supine sleeping position.

Many classifications of POSA patients have been published [1-5] since its introduction by Cartwright in 1991 [6].

The most recent, and in our opinion most comprehensive, is the APOC classification [7]. This classification system stratifies patients into 3 categories according to the possibility of being cured or not by positional therapy (respectively APOC-1, 2, 3).

Positional therapy refers to a group of devices with the aim of avoiding the supine sleeping position.

New evidence [8] suggested that positional therapy can be treated with other therapies, like surgery [9-11], ventilatory therapy or oral device [12], and improve the overall outcome.

In clinical practice, information on sleep posture is generally achieved by data collected from polysomnographic exam (PSG). All PSGs are able to detect body position thanks to an accelerometer positioned within the instrument. These devices are generally fixed on the trunk of the patient, so that the posture recorded refers to the trunk position. In fact, accelerometers inside PSG are not able to record the position of all parts of the body, for example head or neck position. This is a remarkable limit of PSG studies, because previous studies have shown that the position of head and neck can play a key role during the genesis and release of the apnoeic and hypopnoeic events. Zhu et al. [13] reported that head rotation alone can be sufficient, in mild cases, to treat POSA, despite the supine trunk position: they reported a 27% of resolution of apnoeas when OSAS patients turn their head sideways. Ono et al. demonstrated that the Apnoea-Hypopnoea Index (AHI) with the head rotated, despite the supine trunk position, is better than AHI with head supine [14].

It is also widely demonstrated that not only head rotation, but also head extension can have a positive effect on the airway in OSA patients [15-17].

The current trend in positional therapies consists of using sleep position trainers. These are devices worn during sleep that can recognise the patient's position by the use of an accelerometer. These sleep position trainers produce vibrations if the supine position is detected, and the intensity of vibration increases until the patient rotates into a non-supine position, in order to avoid the supine position. They also have a role in diagnostics by recording the sleeping position. Sleep position trainers vary in types and styles, each with its own positioning on the patient's body, e.g. neck, thorax or head.

These different placements can potentially generate a bias between body posture registered by the PSG (position detector is always on the thorax) and by sleep position trainer (position detector may be on the neck). In this view, the results of positional treatment can be affected by important bias.

Prior to evaluate efficacy of any positional therapy, it is mandatory to know if the recording systems are reliable in correctly detecting sleeping position.

The aim of this study is to detect the reliability of different devices on assessing sleeping position, comparing the results obtained in the same subject with objective evaluation by an infra-red camera.

We compared the positional data obtained from a modern type III PSG (cardiorespiratory monitoring device, Nox T3) and a sleep position trainer (Night Shift - NS) during the same night.

Materials

Subjects

We recruited 4 young and healthy Italian volunteers, aged between 29-32 years, 3 males and 1 female. There was no previous clinical history of snoring or OSAS. The participants were non-obese subjects (mean BMI 24.6 kg/m^2).

The subjects agreed to participate to the study, and consent was given according to local ethical approval.

Neck worn device

NS Sleep Positioner (Advanced Brain Monitoring, Carlsbad, CA) is composed of a plastic device fastened on the back of the neck with an adjustable rubber strap secured by a magnetic clasp (Fig. 1).

Neck positions are reported as upright, supine, lateral left, lateral right and prone. Upright is assigned when the neck angle is ≥ 60° around the horizontal axis [18]. Supine is assigned when the neck angle to the left/right is < 43° around the vertical axis. Lateral left or right is assigned when the neck angle exceeded 47° around the vertical axis. The NS assumes the patient has remained in the previously assigned position when the neck angle falls between 43° and 47° around the vertical axis. Prone is the mirrored position of supine with the additional requirement that the Z-axis is < -15°. See Figure 2 for more details.

Polygraphic recording

Polygraphic recording was performed by NOX-T3 cardiorespiratory monitoring (Nox Medical, Reykjavik, Iceland). It consists of different sensors: nasal cannula, thoraco-abdominal straps, pulse oximeter and accelerometer. The nasal cannula detected the nasal airflow. Thoraco-abdominal

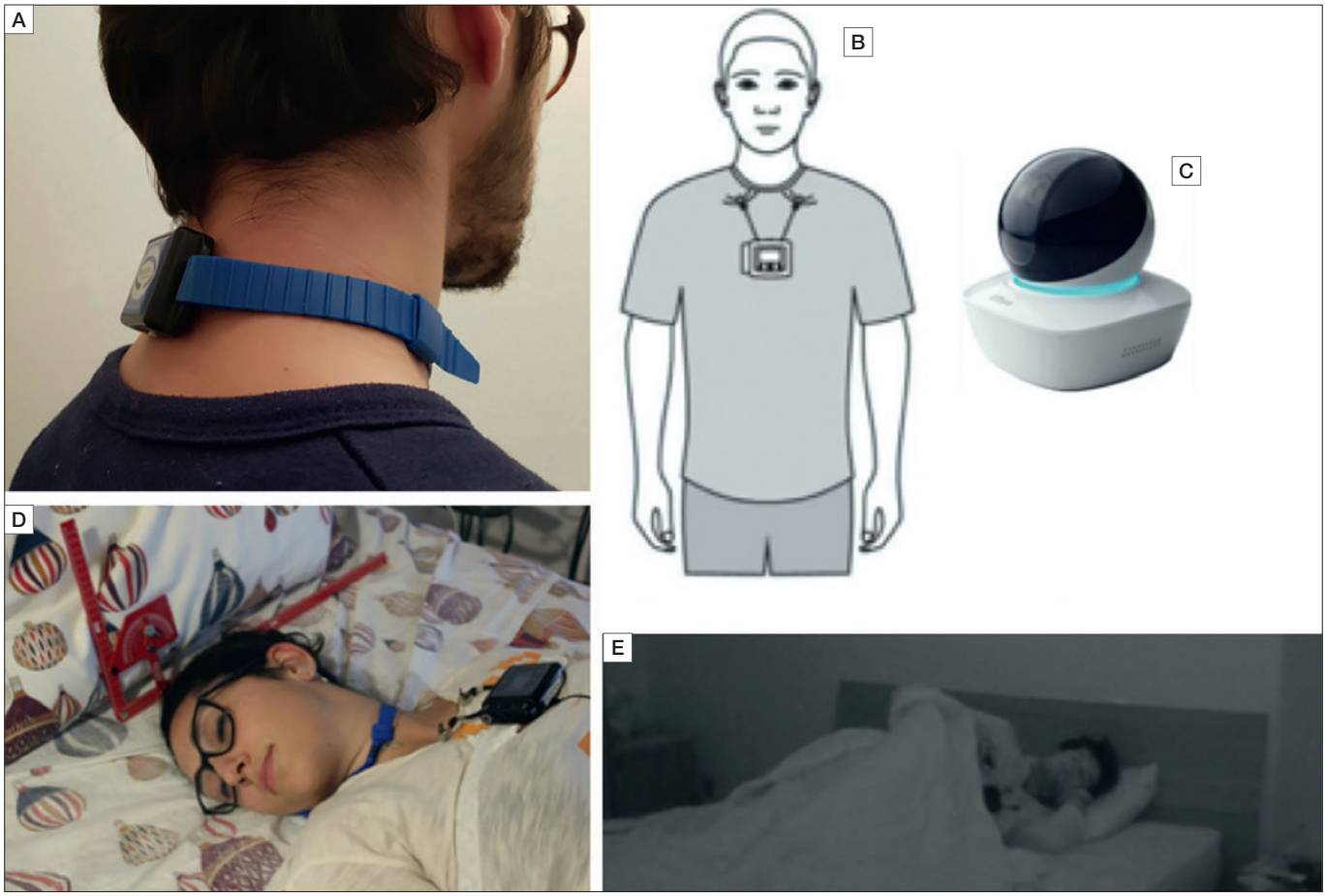

Figure 1. (**A**) example of how to wear Night Shift Positioner. Note the position behind in the neck; (**B**) how to place the NOX T3 device with clips to the thorax; (**C**) Infra-red camera; (**D**) image of combination of NS +PSG. Note the position of the NOX-T3 on the thorax and the neck worn device (NS). (**E**) Nocturnal view from the infra-red video-recording.

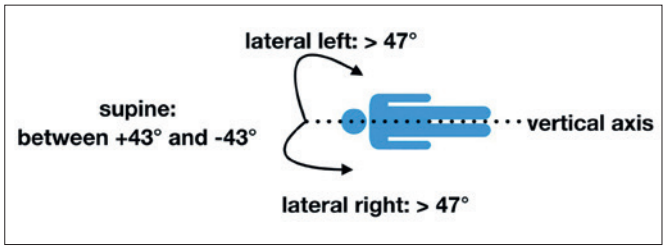

Figure 2. Superior view, patient lying supine. Note the vertical axis, which is orthogonal in comparison to the patient's plane.

straps monitor the thoraco-abdominal movement by RIP (respiratory impedance plethysmography). A pulse-oximeter detected heart rate and oxygen saturation. The plastic device is fastened on the thorax to the patient's shirt with clips. It contains an accelerometer inside, which is able to detect body position and the patient's movements. In this way, NOX-T3 is able to identify the position of the thorax.

Video recording

A video recording was performed by two high resolution infra-red cameras (Dahua IPC-A35, 3.6 mm lens, 3 MP, 20 fps/1080 pixels). The cameras recorded an mp4 file of the entire night session.

Methods

The inclusion criteria were:

1. age > 18 years old;
2. BMI < 30 kg/m^2.

The exclusion criteria were the presence of any factor that could affect body sleeping position, such as:

1. neck or shoulder pain;
2. previous orthopaedic surgery (e.g. arm or leg fractures, arthroprosthesis);
3. pregnancy;
4. use of hypnotic drugs or alcohol consumption;
5. previous clinical history of snoring, apnoeas, daily sleepiness.

Patients spent one night sleeping in their bed in their own home, wearing simultaneously the neck worn device (NS) and a cardiorespiratory monitoring device (NOX-T3).
The NOX-T3 was fully equipped with nasal cannula, thoraco-abdominal straps, pulse oximeter and accelerometer in order to record the cardio-respiratory parameters of the subjects during night.
To record body position, we used different devices: a polysomnography (NOX-T3, cardio-respiratory-monitoring), placed on the thorax, and a sleep position trainer (NS), placed on the neck.
To obtain an objective assessment of the patient's sleeping position, we simultaneously recorded a video using the two infra-red cameras, both synchronised with the other two devices (NS and NOX-T3).
The cameras were placed respectively on one side (left conventionally) and at the foot of the patient with a 90° angulation compared with the vertical and longitudinal axis of the patient, as seen in Figure 3.
Patients were advised not to cover their head, neck or thorax with a blanket, in order to ensure good visualisation by the infra-red cameras.
All devices (NS, PSG and video cameras) were switched on manually and simultaneously by the patients themselves while going to bed.
The recording time was impressed on the video tape to compare, time after time, body position identified by the video with the data from the other two devices.
We synchronised the time of all devices, in order to analyse the data obtained simultaneously. To better relate the data obtained, we manually set the degrees in which the PSG detects sleeping position according to the data set on the NS.
NS was used in diagnostic mode. This means that the device does not vibrate if patients were lying supine, but was able to collect data about sleeping position.
The NS, being placed around the neck, could give information about the head and neck segment.
The data was downloaded from NS with its specific software, which was able to illustrate the body position during time and assessing the percentual time spent in supine position. Figure 4 shows the NS report. The first line shows patient's night movements, with a different height of the line proportionally to its intensity. The second shows the

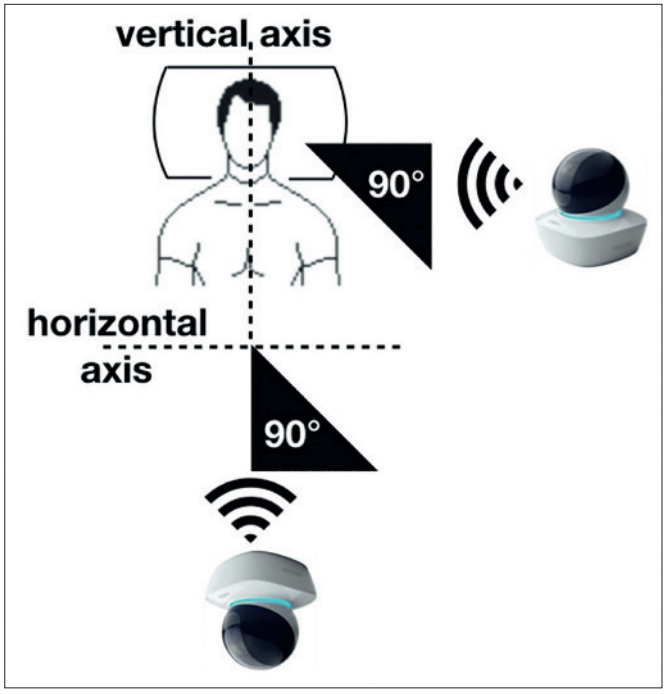

Figure 3. Disposition of cameras. One camera is positioned on one side, and one camera at the foot of the patient. Each camera has a 90° angle in relation to the patient.

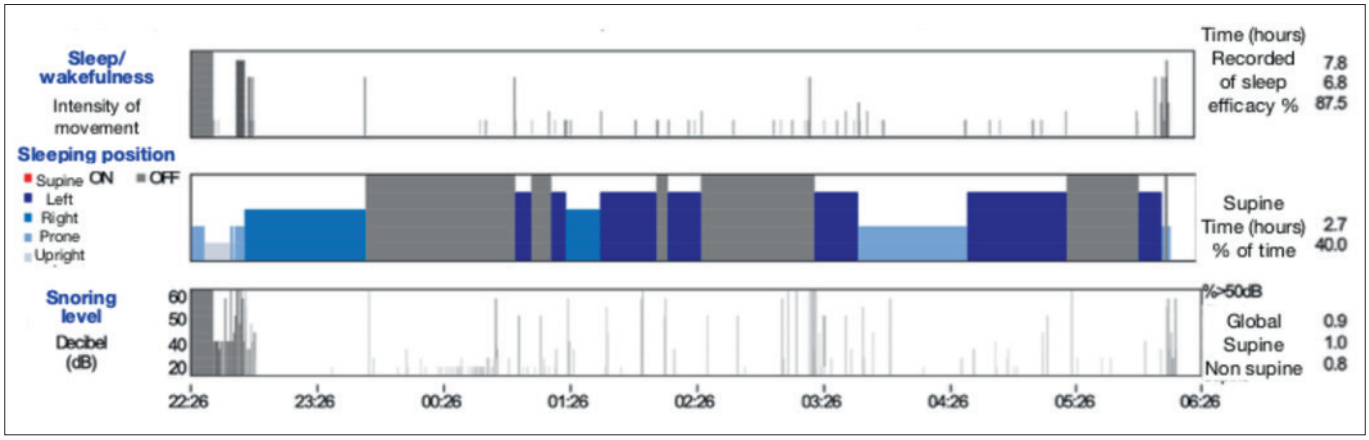

Figure 4. Night shift data report.

patient's position (supine, left, right, prone). The last shows the loudness of snoring expressed in decibel (dB). Under the graph, there is time of night in which the events occur.
Figure 4 also shows that NS is able to detect movements of the patients and the noise (expressed in decibel dB) of snoring.
The comparison between two of the three method of position recording (PSG, NS and video camera) allows to evaluate the reciprocal position of two different body segment ("thorax" and "head and neck") and to compare the efficacy of the single device realted with the secure position data from the camera.
All possible comparisons are listed in the Table I.
The study was approved by the Institutional Ethical Committee and was conducted according to the principles stated in the Declaration of Helsinki "Ethical Principles for Medical Research Involving 'Human Subjects".

Data analysis

Downloaded data from NOX-T3 were analysed with the software Noxturnal version 5.1.220294. Standard 2012 AASM criteria [19] were used to score apnoea and hypopnoea events on the PSG.
Downloaded data from NS were analysed with the specific software (Advanced Brain Monitoring 2016 – Posas Software).
Sleep reports from NS and NOX-T3 were compared to each other and the video recording.
Each sleeping time was divided into epochs. An epoch is the period of time between two body movements recorded by PSG, NS and/or video.
From each period we reported the position of the head and neck region and the trunk (for example supine, left, prone, right) seen in the video and we compared it with the position recorded by PSG and NS in these periods.

Results

The PSG analysis confirmed that subjects were not OSAS patients: mean AHI was 2.8/h (range 4.9-0.3/h), mean ODI 2,5/h (range 0.2-5.8/h), mean supine AHI 2.6/h (range 0-5.2/h), non-supine AHI 2.9/h (range 0.4-5.1/h).

Mean supine time

The mean supine time recorded by NS and PSG was, respectively 39.5 and 37.8%.
The PSG revealed a mean right sided sleeping of 21.55% of total sleep time, a left sided sleeping time of 24.1% and a prone sleeping of 16.4%.
Table II shows, subject by subject, the differences between supine recording time by PSG and NS.

Epoch by epoch

The concordance between the position recorded by NS and PSG in each epoch between two body movements was 87%, as seen ** in Table III. This concordance was higher in 3 subjects (mean 95.6% range 0.91-1.00). Subject 4

Table I. Clinical meaning of comparison between the different methods.

Comparison	Methods		Clinical meaning of the comparison
Mean supine time	NS	PSG	Do they (NS and PSG) agree evaluating the average supine time position?
Epoch* between 2 body movements	NS	Head and neck (video)	Does NS give correct information about head and neck position?
	NS	Thorax (video)	Does NS give correct information about thorax position?
	NS	PSG	Do they (NS and PSG) agree evaluating the supine time position time by time?
	PSG	Head and neck (video)	Does PSG give correct information about head and neck position?
	PSG	Thorax (video)	Does PSG give correct information about thorax position?
	Head (video)	Thorax (video)	In which proportion do head & neck and thorax behave as a single segment?

** An epoch is a single time body position, expressed by time between two body movements recorded by PSG, NS and/or video.*

Table II. Supine time (%) for each subject recorded by NS and PSG and its concordance rate.

	Supine time (%) recorded by NS	Supine time (%) recorded by PSG	Concordance rate
Subject 1	40	41.5	-0.96*
Subject 2	34	27.9	0.82
Subject 3	72.8	70.7	0.97
Subject 4	11.3	11.1	0.98
Mean	39.5	37.8	0.93

** In this case there is a negative concordance, because supine time % recorded by PSG is bigger than supine time % recorded by NS.*

Table III. This table shows for each epoch, subject by subject, the concordance rate between the different methods of position recording.

Concordance epoch by epoch	PSG/trunk video	NS/head & neck video	Head & neck/ trunk video	NS/PSG	NS/ trunk VIDEO	PSG/head & neck video	Supine time PSG/NS
Subject 1	1	0,28	0.28	1	1	0.32	-0.96
Subject 2	0.92	0.87	0.75	0.96	0.96	0.79	0.82
Subject 3	0.87	0.43	0.48	0.91	0.96	0.39	0.97
Subject 4	1	0.5	0.31	0.63	0.63	0.56	0.98
AVERAGE	0.95	0.52	0.50	0.87**	0.88	0.52	0.93

** $p < 0,005$.

showed a low concordance rate (63%). This subject spent a lot of time in the prone position, with a higher grade of rotation of his head seen by the video recording while lying in prone position. In this case, while the PSG with his sensor placed on the chest detected the prone position, the NS applied on the posterior part of the neck recorded right or left rotation of the head and neck segment. This bias did not influence supine sleeping time, because these (head rotated and prone) are non-supine types: concordance between NS and PSG according to supine position was nonetheless the highest (0.98) in subject 4.

Lying in the prone position, it is very difficult not to one's rotate head because of the impossibility to breathe through a pillow. The grade of rotation of the head was higher than in supine position.

The agreement between the position of the head (according to the video) and the trunk seen in the video was 46%: this means that rarely while patients were lying on their back was the head supine too, in only 46% of epochs.

The grade of rotation of the head was, in these cases, lower than in prone position, and the NS recorded the supine position, despite the mild grade of rotation of the head.

The agreement between the head position recorded by video and NS was 52%. This was similar to the agreement between PSG and head position seen in the video.

Discussion

In clinical practice, information about sleep posture is generally collected by PSG. All PSGs are able to detect body position thanks to an accelerometer positioned within the instrument. These devices are generally fixed on the trunk of the patient, so the posture recorded refers only to the trunk position.

Positional therapy refers to a group of devices with the aim of avoiding the supine sleeping position.

There are different kinds of sleep position trainers, each with its own positioning on the patient's body, which can be the neck, thorax, or head.

These different placements can potentially generate a bias between body posture registered by the PSG (position detector is always on the thorax) and sleep position trainer (position detector may be on the neck).

This is the first study to evaluate sleeping position recorded simultaneously by a diagnostic device (PSG) and a therapeutic positional device. As control, we recorded the entire night with two infrared cameras.

NS was mainly chosen as a sleep positional trainer for its ability to also work in diagnostic mode, in order to record the body's position without producing any vibration in the supine position. Its effectiveness in POSA treatment has been demonstrated [18].

Prior to evaluating the efficacy of positional therapy, it is mandatory to know if the recording systems available are reliable in correctly detecting sleeping position. For this reason, we decided to recruit healthy young volunteers, without a previous history of snoring or OSAS.

We performed a cardiorespiratory monitoring for one night while patients were sleeping in their bed to confirm the absence of OSAS. We decided not to remove the sensors in order to simulate the footprint of the full device and its impact on sleeping.

Despite the presence of cardiorespiratory data, the aim of this study was not to evaluate the efficacy of positional therapy, but rather correct assessment of sleeping position by different devices.

Healthy, young volunteers were recruited to exclude any potential bias due to BMI, OSAS and muscle-skeletal pathology.

Our results show that NS is a good tool to assess the position of the trunk, with a high rate of agreement with PSG (epoch by epoch 95.6%, supine time 93%), even if it's positioned around the neck.

Nevertheless, if patients spend a lot of time in the prone position, NS makes mistakes: concordance between NS and PSG, in this case, was lower (e.g. subject 4, 62%).

Fortunately, because the aim of NS is to avoid the supine position, these mistakes do not impact the outcome of the device: and prone position is a non-supine position.

Consequently, NS can be used to avoid a supine position of the trunk in its therapeutic modality. Many studies have

demonstrated its efficacy [18]. However, despite the fact that it is a neck worn device, it is not able to detect the actual position of the head and neck segment (Tab. II). Previous studies have reported that head rotation can be sufficient, in mild cases, to treat POSA, despite the supine trunk position: Zhu et al. [13] reported 27% of resolution of apnoeas in OSAS patients when the head is rotated laterally.

Van Kesteren et al. [20] demonstrated that, especially in POSA patients, head position has a fundamental role in the genesis of apnoeas. Simply with head rotation, the anteroposterior collapse of the tongue due to gravity forces can be avoided and the airway can be stiffened. AHI with the head rotated, despite the supine trunk position, is better than AHI with head supine [14]. Our population consisted of healthy subjects, so that we could not assess the contribution of head and trunk position on apnoeas.

Other studies suggested, on the contrary, the predominant role of the position of the thorax in worsening sleep apneas. Joosten S.A. and colleagues [21] demonstrated a 13% functional residual capacity (FRC) decrease in the OSA group when moving from lateral to supine. This reduction of FRC influences upper airway collapsibility with resultant changes in upper airway pressure [22,23]. A loss of lung volume can raise upper airway collapsibility (Pcrit) so much that this triggers upper airway obstruction in a vulnerable airway. In addition, a reduced lung volume increases the loop gain of the ventilatory control system during sleep by reducing lung oxygen and carbon dioxide stores that may therefore contribute to breathing instability in the supine sleeping position [24].

The PSG accelerometer, due to its position on the thorax, cannot assess the head or neck position. Standard PSGs do not include head position to differentiate between head and trunk position in POSA patients. For this reason, we tried to associate NS and PSG, thinking that the former could provide adjunctive information about neck and, consequently, head position.

Nevertheless, the agreement between the position recorded by NS and head/neck position (seen in the video recording) was very low (52%).

In 46% of cases, the head and trunk were not in the same position; in other words, if NS would be active with vibration, patients would be forced to rotate to one side, even if they already had rotation of the head, potentially curative of their apnoeas.

Further studies might develop and investigate new devices that are able to detect both head and trunk position. POSA therapy has to be tailored to PSG findings, but usually these devices lack any information about head position. If apnoeas are present while patient is lying with trunk supine, which position should be avoided to cancel apnoea? Why force patients lying on their side the whole night, when maybe simple head rotation could resolve the apnoea? Positional therapy can be effective, but shoulder complications are a common and unpleasant side effect of this therapy [25].

With this study we could not assess the efficacy of NS on apnoeas, but our data show that, even if NS is a neck worn device, its information is in agreement with the thoracic device.

The greatest limitation of our study is some subjectivity in visual position assessment of the overnight video recording. At times it was difficult to determine if head position was greater than or less than 45° from the vertical plane.

Another limitation of this study is the fact that we evaluated head rotation, but not flexion or extension, considering its potential role in the genesis of apnoeas [16]. Choi et al. [15] demonstrated that neck flexion significantly increases airway resistance in patients with OSA, maintaining the head in extension preserves airway patency.

In contrast with the previous study, Skinner et al. [17] suggested that any potential effect attributable to neck flexion would be smaller than reducing in the negative effect of gravity on the upper airway with an elevated posture.

Further studies should evaluate head position, considering the wide range of possible movements and its correlation with apneas.

In the literature, a new plug-in accelerometer module for the PSG system that is able to detect head position is available [26], but in our opinion it does not work with all the PSGs used in common clinical practice.

In our opinion, the integration of a system like this, even if it could be improved upon, can give useful information about the reciprocal position of head and neck, which is necessary to correctly treat POSA patients.

The next step would be to apply these devices to the OSAS population, if good indications have been obtained from healthy subjects.

Conclusions

This pilot study confirmed that more information about sleeping body position is needed, especially in POSA patients in which positional therapy can have potentially good outcomes. We hope that the results of this study will highlight the need to develop new sensors that are able to identify head, neck and thorax positions. This technical development is needed to better diagnose and treat POSA patients.

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