Sleep and Breathing (2019) 23:1141–1149
https://doi.org/10.1007/s11325-019-01792-9

SLEEP BREATHING PHYSIOLOGY AND DISORDERS • ORIGINAL ARTICLE

Treatment of sleep-disordered breathing with positional therapy: long-term results

Jolien Beyers[1,2,3] · O. M. Vanderveken[1,2,3] · C. Kastoer[1,2] · A. Boudewyns[1,2] · I. De Volder[3,4] · A. Van Gastel[3,4] · J. A. Verbraecken[2,3,5] · W. A. De Backer[2] · M. J. Braem[2,6] · P. H. Van de Heyning[1,2] · M. Dieltjens[1,2]

Received: 15 November 2018 / Revised: 11 January 2019 / Accepted: 26 January 2019 / Published online: 18 February 2019
© Springer Nature Switzerland AG 2019

Abstract

Purpose The aim of the present study was to assess the efficacy of a sleep position trainer (SPT) in patients with an established diagnosis of positional obstructive sleep apnea and to evaluate the adherence after 1-year follow-up.

Methods Polysomnography (PSG) was performed at baseline and after 1 year of SPT use. Patients received questionnaires to assess treatment satisfaction and subjective adherence. Data on objective adherence and number of vibrations initiated by the SPT were collected from the SPT device.

Results Nine out of 58 patients stopped using the SPT during the first year of treatment (16%). Thirty-four middle-aged and overweight patients underwent a PSG after 1 year of SPT use (male/female ratio, 28/6; overall apnea/hypopnea index (AHI), 16/h). A significant reduction in overall AHI to 6/h was observed using treatment ($p < 0.001$). The median percentage of supine sleep decreased significantly to 1% with SPT ($p < 0.001$). The mean objective SPT use in 28 patients was 7.3 ± 0.9 h/night and 69 ± 26% of the nights. Furthermore, 75% of the patients reported a better sleep quality since the start of SPT treatment.

Conclusions Long-term treatment with the SPT was found to be effective in reducing overall AHI. Time spent sleeping in supine position was reduced to almost zero in the continuing users. Patient satisfaction was high when using the SPT.

Keywords Long-term therapy · Obstructive sleep apnea (OSA) · Supine dependent · Sleep position trainer · Non-invasive therapy

Introduction

Sleep-disordered breathing (SDB) has a high prevalence among middle-aged adults, estimated to reach 24% in men and 9% in women [1]. Within the pathophysiological spectrum of SDB, snoring and obstructive sleep apnea (OSA) are the most common and are associated with age and gender [2]. OSA is characterized by recurrent episodes of partial (hypopneas) or complete (apneas) collapse of the upper airway during sleep, finally resulting in cessation of the oronasal airflow, with associated hypoxemia and hypercapnia [3]. Consequences of undiagnosed or untreated OSA include cardiovascular and cerebrovascular morbidity, diminished quality of life, and an increased risk of motor vehicle accidents [4]. This, in turn, leads to major socio-economic consequences [5].

Diagnosis and severity of the disorder are based on the number of apneas and hypopneas per hour of sleep, which is defined as the apnea/hypopnea index (AHI). An AHI between 5 and 15 events/h is considered mild OSA, an AHI between 15 and 30 events/h as moderate OSA, and an AHI above 30 events/h as severe OSA [6].

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11325-019-01792-9) contains supplementary material, which is available to authorized users.

✉ Jolien Beyers
jolien.beyers@uza.be

1 Department of Otorhinolaryngology, Head and Neck Surgery, Antwerp University Hospital, Wilrijkstraat 10, 2650 Edegem, Belgium

2 Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

3 Multidisciplinary Sleep Disorders Centre, Antwerp University Hospital, Edegem, Belgium

4 Department of Psychiatry, Antwerp University Hospital, Edegem, Belgium

5 Department of Pulmonary Medicine, Antwerp University Hospital, Edegem, Belgium

6 Department of Special Care Dentistry, Antwerp University Hospital, Edegem, Belgium

Continuous positive airway pressure (CPAP) is the gold standard therapy for moderate to severe OSA [7, 8] and is an effective treatment improving sleep quality and reducing the cardiovascular and cognitive morbidity [9]. However, despite the high therapeutic efficacy, overall adherence and compliance to CPAP is not optimal due to patient acceptance and tolerance issues [10, 11]. Therefore, there is growing interest in non-CPAP alternatives as a treatment option for patients diagnosed with OSA [10, 12].

Positional OSA (POSA) is a subgroup of OSA that is characterized by the occurrence of more breathing events when sleeping in supine position when compared to non-supine positions. The prevalence of POSA depends on the definition used [13–19] and is influenced by the severity of the disease, with a higher prevalence of POSA in patients with milder forms of OSA [15]. In addition, POSA occurs more often in younger and less obese subjects [17, 18]. One of the treatment modalities for POSA is positional therapy (PT), which has the aim to avoid sleep in the supine position, being the worst sleeping position for POSA patients. Its use is simple and available since a long time, ranging from the "tennis ball method" to positional auditory alarms, vibrational alarms, positional pillows, vests, or simple verbal instructions. PT has been proven effective in reducing the time spent in the supine position during sleep as well as in reducing the AHI [16, 20–25]. However, the long-term adherence and acceptance of positional training techniques such as the tennis ball method is low because a bulky object strapped to the back is uncomfortable and disturbs the sleep pattern [21, 26]. In a recent meta-analysis of Ravesloot et al., 154 patients using the innovative neck-worn and chest-worn vibrational alarms were included, showing a mean decrease in AHI of 11.3 events/h and a mean decrease supine position of 33.6% [27]. These innovative neck-worn and chest-worn vibrational alarms are in general better accepted by the patients in the short-term [16, 23–25], suggesting that the vibrational alarms would be an effective treatment in POSA patients. However, only little information on the long-term use of these devices is available in literature.

The aim of the present study was to assess the long-term clinical efficacy of a sleep position trainer (SPT) and its adherence in a routine clinical setting, both objectively and subjectively 1 year after starting SPT treatment.

Material and methods

Study design

At the Antwerp University Hospital, a clinical pathway and accompanying registry is set up to evaluate the effect of SPT in the individual patient prior to prescription of the therapy and to assess the long-term follow-up of this therapy in routine clinical practice. In patients starting SPT therapy, long-term follow-up of the patients and the therapy is performed using a yearly recall schedule.

We performed a trial period with the SPT before inclusion in the study, to select those patients who would benefit the most from this therapy, as described by our study group in 2018 [28]. After this trial period, patients could decide whether or not to continue treatment with the SPT.

From July 2015 to October 2017, patients who purchased the SPT were contacted for a follow-up visit after 1 year. Patients underwent a full attended type 1 polysomnography (PSG) in the hospital and were asked to complete a number of questionnaires to assess sleepiness (the Epworth sleepiness scale, ESS), snoring (visual analogue scale for snoring, VAS), satisfaction on sleep quality, user-friendliness and ergonomic aspects of the SPT, and subjective adherence to the SPT therapy. Data on the objective use of the SPT and on the number of vibrations given by the SPT was read out directly from the SPT device.

Study subjects

Patients diagnosed with POSA that started SPT therapy in routine clinical practice were included in a registry.

POSA was defined as having an overall AHI ≥ 5/h, a supine AHI at least twice as high as the non-supine AHI, and 10–90% of the total sleep time (TST) spent in the supine position [28].

Sleep position trainer

The SPT is a small, lightweight (72 × 35 × 10 mm, 25 g), chest-worn device, placed at the sternum (NightBalance™, Delft, The Netherlands) (Fig. 1). It monitors body position and provides a vibration stimulus when in supine position for more than 10 s. The SPT allows for body position changes during sleep, without any movement restrictions. In order to stop the vibrations, the patient has to shift to a non-supine position. If the patient is not changing position, the frequency

Fig. 1 The sleep position trainer used in this study

of the vibration stimulus will change and its amplitude and duration increase gradually until the patient effectively switches to a non-supine position. Objective information on adherence and vibrational feedback was obtained from the data stored in the SPT.

Polysomnography

Diagnostic assessment and follow-up of patients was performed by a type 1 PSG. Sleep stages, airflow and respiratory effort, snoring, leg movement, electrocardiography, oxygen saturation, and body position were measured during this overnight stay in the hospital. Sleep stages were determined by the use of electroencephalography, electromyography, and right and left electrooculography. Nasal airflow was evaluated by the use of an external thermistor and nasal pressure cannula. Respiratory effort was measured by respiratory inductance plethysmography. Oxygen saturation was measured with pulse oximetry using a finger probe. Snoring events were recorded. Qualitative snoring signals were obtained from a microphone. Body position was monitored with a piezo-electrical sensor in order to distinguish between upright, supine, prone, left, and right sleeping posture.

Finally, all sleep stages were scored manually according to the guidelines of the Belgian National Social Security System (RIZIV/INAMI) being a combination of the AASM 1999 and 2007 scoring rules [6, 29]. A total cessation of airflow > 10s was defined as an apnea, while a hypopnea was defined as a decrease in airflow ≥ 30% from baseline associated with an oxygen desaturation ≥ 3% and/or an arousal. The mean amplitude of stable breathing in the 2 min preceding onset of an event in individuals with a stable breathing pattern during sleep or the mean amplitude of the three largest breaths in the 2 preceding minutes when breathing pattern was unstable were defined as baseline.

Questionnaires

During their out-patient visit, the patients received a set of questionnaires to collect information on treatment satisfaction and long-term use. They were provided with a self-developed questionnaire including 16 questions about snoring, sleep quality, use of the SPT device, and adherence (appendix in the ESM). Furthermore, patients were asked to complete the ESS and VAS for snoring.

Definitions

Therapeutic efficacy is defined as a reduction in overall AHI. Responders were defined as patients with a reduction in AHI ≥ 50% when using the SPT as compared to baseline, and non-responders as patients with a reduction in AHI < 50% from baseline. Treatment success was achieved when an AHI below 5 events/h of sleep was achieved with the SPT therapy.

Statistical analysis

Data were analyzed using SPSS (version 24, Statistical Package for Social Sciences Inc., IBM, Chicago, Illinois, USA). Descriptive statistics for patients' characteristics were presented as means ± standard deviation (SD). The Kolmogorov-Smirnov test was performed to assess the normality of data distribution.

Data were expressed as median values or their lower and upper quartiles (Q1, Q3) when not normally distributed and analyzed by an independent samples Mann-Whitney *U* test. Categorical variables were tested using Pearson's chi-square test, and the nonparametric Wilcoxon-signed rank test was used to test changes in parameters before and after treatment, to compare subjective and objective adherence and to compare the results of PSG and SPT in terms of percentage of reduction in supine sleep. A p value < 0.05 was considered a statistically significant result.

Results

Polysomnographic data

The patient flow is presented in Fig. 2. A total of 58 patients who purchased the SPT after the 1 month trial period [28] were contacted for a follow-up PSG 1 year after the start of SPT therapy.

Forty-nine patients out of 58 were still using the SPT after 1 year leading to a continuation rate of 84.5%. Nine patients (15.5%) stopped using the SPT. One out of these 9 indicated he learned to avoid the supine position during sleep, 1 patient claims the effect disappeared on the long-term, another patient had an accident making non-supine sleep painful, 1 patient became asymptomatic and did not want treatment anymore, and 5 patients did prefer other treatment on the long-term.

Fifteen patients were still using the SPT but were not interested in a follow-up PSG (25.9%). The efficacy in these patients could not be evaluated objectively; however, they mentioned to be satisfied with SPT treatment. As a result, a total of 34 patients out of 58 (58.6%) underwent a full PSG after 1 year of treatment (Table 1). The parameters of this study population at baseline and after 1 year of SPT therapy are presented in Table 1.

After 1 year, the overall AHI, the percentage of supine position and the supine AHI decreased significantly with SPT treatment ($p < 0.001$) (Fig. 3) as well as the oxygen desaturation index (ODI) ($p = 0.002$) and the minimum oxygen saturation (SpO_2) ($p = 0.047$).

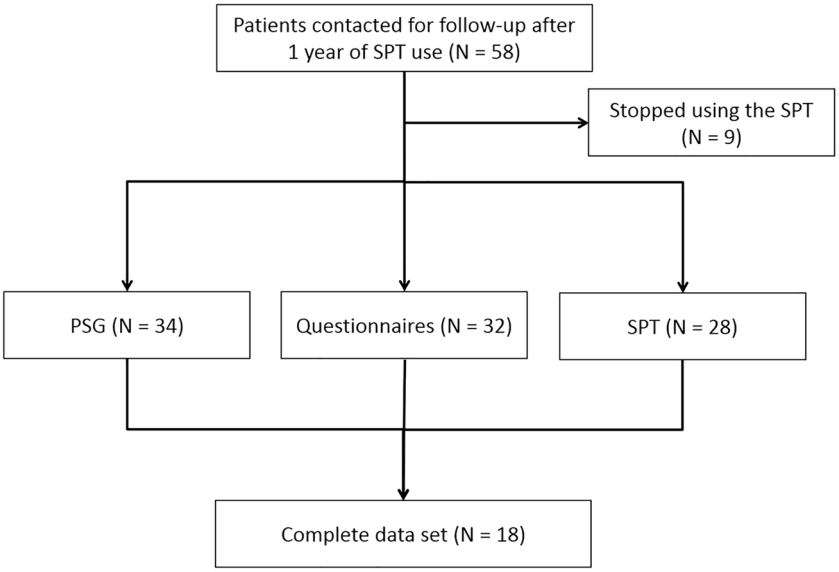

Fig. 2 Patient flow of this study. A total of 58 patients were contacted for a follow-up after 1 year of SPT use. The study consisted of a full PSG ($n = 34$), questionnaires ($n = 32$), and data read out of the SPT device ($n = 28$). A complete data set was collected in 18 patients. PSG polysomnography, SPT sleep position trainer

Based on the therapeutic efficacy calculations, 18 responders and 16 non-responders were noted. In the responder group, a significant reduction in AHI, AHI supine, percentage of supine sleep ($p < 0.001$), ODI ($p = 0.011$), and a statistically significant increase in minimum SpO_2 was seen ($p = 0.003$). In the non-responders, the supine position as well as the AHI in supine position were significantly reduced with SPT compared to baseline ($p = 0.004$ and $p = 0.049$). However, the AHI in the non-supine position increased significantly ($p = 0.005$), explaining the small increase in the overall AHI in the non-responder group from 15.4 (8.8; 20.7) events/h to 17.0 (9.2; 19.5) events/h. At baseline, a significant difference in the percentage of supine position was found ($p = 0.006$) for both groups: the responder group showed a median of 57% supine position, while the non-responder group showed a median of 27% supine position. No differences were seen in age ($p = 0.231$), gender ($p = 0.100$), ESS ($p = 0.752$), VAS ($p = 0.505$), overall AHI ($p = 0.064$), supine AHI ($p = 0.851$), ODI ($p = 0.468$), mean oxygen saturation ($p = 0.956$), and minimum oxygen saturation ($p = 0.341$) between responders and non-responders.

Questionnaires

Completed questionnaires were obtained from 32 patients showing a sleep quality mean score of 7.1 ± 1.7 on a scale of 10. In 24 patients (75.0%), subjective sleep quality improved since the start of the treatment with SPT.

A mean score of 6.6 ± 2.0 on 10 was reached on the comfort of sleeping with the SPT. The subjective depth of sleep increased from 4.9 ± 1.7 to 7.1 ± 1.7 on a scale of 10.

In 21 patients (65.6%), daytime sleepiness was considered satisfactory with SPT-treatment. However, only 17 patients (53.1%) reported being satisfied regarding snoring.

Twenty-five patients (78.1%) reported to wake up occasionally as a result of the vibrations sent out by the SPT, also disturbing the bed partner of 7 (21.9%) patients. Twelve of the patients (37.5%) woke up by the sound produced during the vibrations as well as the bed partner of 9 patients (28.1%).

The patients reported an average SPT use during 5.8 ± 1.8 nights per week (82.9%) for 6.7 ± 1.6 h per night. Subjective total sleep time was 7.2 ± 0.9 h per night.

SPT data

Data read out from the SPT could be collected from 28 patients during an out-patient visit. Mean percentage of days the SPT was used was 68.6 ± 25.6% with a mean SPT use of 7.3 ± 0.9 h per night. The percentage of supine sleep decreased statistically significantly from 28.3 ± 18.2% during the first week of SPT use to 13.1 ± 17.9% during the last week of follow-up ($p < 0.001$), which is a reduction of 60.9 ± 31.4%. Differences in SPT use during the first week compared to the last week of use are presented in Table 2. No statistically significant differences were found in the number of vibrations generated, the response to the vibrations, nor in the response rate (Fig. 4).

Full data set

In 18 patients out of 34 patients, a complete dataset with both subjective and objective data (for PSG as well as SPT read out) could be obtained, see Table 3. A significant reduction in overall AHI ($p = 0.004$), AHI supine ($p = 0.006$), percentage of time spent supine ($p < 0.001$), and ODI ($p = 0.008$) was found.

A subjective overestimation in the number of nights the device was used could be noted, with a subjective average

Table 1 Anthropometric and polysomnographic parameters at baseline and with SPT

Characteristic	Total group			Responders			Non-responders		
	Baseline	With SPT	*p* value	Baseline	With SPT	*p* value	Baseline	With SPT	*p* value
Male/female, number	28/6			13/5			15/1		
Age, years	54.8 ± 8.3			56.5 ± 8.7			53.1 ± 7.7		
BMI, kg/m^2	27.2 (25.6; 28.3)	27.3 (24.7; 28.7)	0.739	26.9 (25.7; 28.4)	27.3 (24.4; 28.7)	1.000	27.2 (25.3; 28.3)	27.4 (25.1; 28.8)	0.604
AHI, events/h	16.40 (12.25; 23.28)	6.2 (3.13; 15.83)	< 0.001*	20.2 (14.5; 25.7)	3.4 (2.9; 5.7)	< 0.001*	15.4 (8.8; 20.7)	17.0 (9.2; 19.5)	0.379
AHI supine, events/h	42.65 (23.13; 58.45)	2.6 (0; 25.6)	< 0.001*	40.5 (24.1; 54.2)	0.0 (0.0; 16.9)	< 0.001*	45.9 (17.4; 60.7)	5.6 (0.0; 47.7)	0.049*
AHI non-supine, events/h	5.20 (2.30; 8.50)	4.95 (2.93; 9.73)	0.198	5.3 (2.9; 7.4)	3.2 (2.2; 5.0)	0.072	4.4 (2.3; 11.0)	10.8 (5.2; 15.8)	0.005*
Time spent in supine position, % TST	37.10 (21.20; 58.10)	1.4 (0; 11.45)	< 0.001*	56.5 (37.1; 66.2)	2.8 (0.0; 6.7)	< 0.001*	27.0 (17.6; 34.3)	1.4 (0.0; 15.0)	0.004*
ODI, events/h	6.00 (2.58; 9.88)	2.50 (1.40; 4.70)	0.002*	5.7 (2.8; 9.4)	1.7 (0.6; 3.2)	0.011*	8.1 (2.6; 10.2)	4.3 (2.2; 8.4)	0.079
Mean SpO_2, %	95.10 (94.28; 95.83)	95.30 (94.73; 96.05)	0.308	95.1 (94.2; 95.7)	95.2 (94.7; 96.1)	0.450	95.1 (94.6; 95.8)	95.4 (94.8; 95.7)	0.679
Minimum SpO_2, %	86.50 (84.00; 89.00)	89.00 (84.25; 91.00)	0.047*	87.0 (84.0; 89.3)	91.0 (89.0; 92.0)	0.003*	85.0 (82.8; 87.3)	84.5 (77.0; 89.3)	0.977
REM stage, %	18.90 (15.75; 21.63)	21.20 (17.7; 24.68)	0.077	17.5 (14.3; 20.4)	20.1 (17.1; 23.8)	0.147	20.0 (17.5; 23.1)	23.5 (17.7; 25.7)	0.277
S1 stage, %	8.00 (6.50; 10.48)	7.2 (5.83; 9.68)	0.472	8.0 (7.3; 9.6)	6.3 (4.7; 8.9)	0.088	7.8 (4.3; 12.4)	7.8 (6.7; 12.0)	0.569
S2 stage, %	53.65 (47.08; 57.05)	49.75 (46.25; 55.83)	0.191	53.0 (46.5; 55.8)	51.6 (46.6; 55.8)	0.756	54.6 (48.3; 57.1)	49.2 (44.9; 53.7)	0.098
S3 stage, %	20.25 (13.63; 23.23)	20.15(15.03; 23.75)	0.322	22.1 (17.0; 23.9)	20.6 (16.2; 23.8)	0.918	16.2 (13.0; 22.4)	19.8 (14.7; 23.3)	0.215
ESS	8.5 (3.75; 12.25)	7.5 (4; 12.25)	0.765	8.5 (6.8; 12.3)	6.0 (4.0; 11.8)	0.329	8.5 (3.0; 12.8)	8.5 (6.0; 13.3)	0.549
VAS Snoring	3.0 (0;6)	2.0 (0.5;5)	0.312	4.0 (0; 8.5)	2.0 (0; 5)	0.083	2.5 (1.3; 3.8)	2.8 (1.3; 4.8)	0.838
Snoring, %	26.70 (8.45;37.63)	17.25 (0;62.45)	0.421	22.8 (9.3; 34.2)	16.8 (0.0; 67.2)	0.234	27.4 (6.0; 42.2)	17.3 (0.0; 60.9)	0.959

Results in mean ± standard deviation, median (quartile 1; quartile 3). Sleep stages are expressed as the percentage of the total sleep time

SPT sleep position trainer, *BMI* body mass index, *AHI* apnea/hypopnea index, *TST* total sleep time, *ODI* oxygen desaturation index, *SpO_2* oxygen saturation, *ESS* Epworth sleepiness scale, *VAS* visual analogue scale for snoring

*Indicates statistically significant findings at the 0.05 level

Total group: $N = 34$; responders: $N = 18$; non-responders: $N = 16$

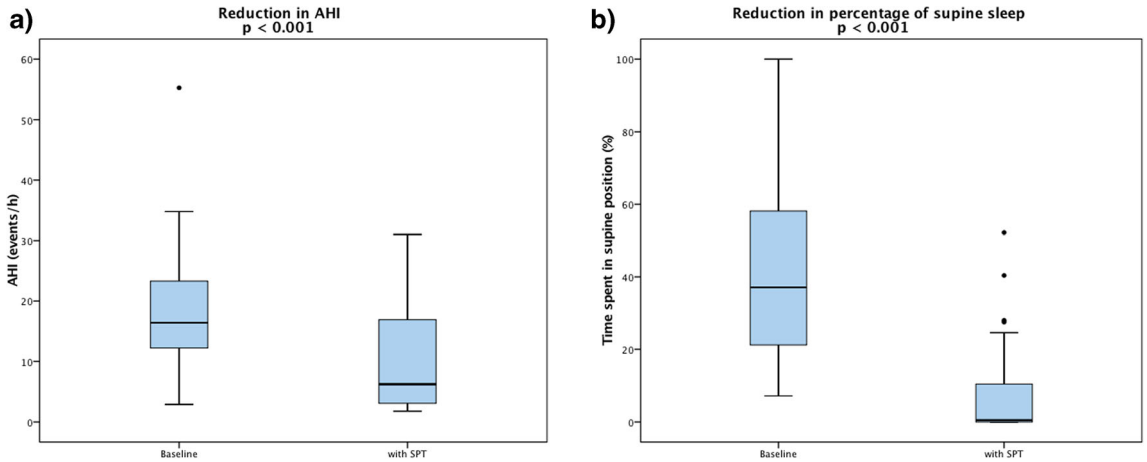

Fig. 3 Median **a** AHI and **b** time spent in supine position at baseline and with SPT treatment. AHI apnea/hypopnea index, SPT sleep position trainer

of 80.2% of the nights used, compared to an objective average adherence of 60.2% ($p = 0.001$).

Finally, the comparison of the reduction in supine sleep based on PSG and SPT showed a mean reduction in supine sleep of 65.6 ± 30.2% for the SPT data and 90.8 ± 17.3% for the PSG data ($p = 0.001$).

Discussion

In the present study, we found that the SPT significantly reduced the AHI, ODI, and percentage of supine position and increased significantly the minimal SpO_2 after 1 year of SPT therapy in a routine clinical practice setting in patients with POSA. These results are in agreement with those reported earlier in the studies of van Maanen et al. [25] and de Ruiter et al. [30]. In addition, a significant reduction in supine AHI was reported in our study, which can be explained by a decrease in the time spent in supine position to zero in the majority of the patients. As a result of the absence of supine position in most patients, the AHI in the supine position decreased to zero as well in these patients.

In the total group of 34 patients, 18 were classified as responders. At baseline, the responders slept significantly more in supine position compared to the non-responders. This means that, in our study, patients who are more likely to sleep in supine will benefit more from positional therapy. The present findings, however, showed a significant increase after 1 year in the AHI in the non-supine position in the non-responder group. This finding emphasizes the importance of follow-up on the long-term, which of course holds true for any chronic treatment for OSA.

Subjectively, the majority of the patients (75.0%) stated that their sleep quality improved, despite the fact that 78.1% reported waking up occasionally as a result of the vibrations. In addition, 65.6% of the patients described satisfaction in terms of a reduced daytime sleepiness, which may correspond to subjectively improved sleep quality. Finally, only 53.1% of the patients were satisfied in terms of snoring.

There was no difference in the number of vibrations that were generated during the first week of SPT use when compared to the last week of follow-up, neither in the response to the vibrations or response rate. This indicates that the patients do not condition to avoid the supine position after 1 year of SPT use, supporting the necessity of ongoing use of the SPT device. Our study does not support the concept that patients learn to avoid sleeping supine after using an SPT for a while.

Based on objective measurements, the patients used the SPT for 68.6% of the nights for 7.3 h/night after 1 year. Subjectively, the reported adherence was 83.0%, for 6.7 h/night. So there is a significant overestimation of the subjective adherence. This is also known in CPAP therapy, where overestimation is up to 1 h per night [11]. A comparable

Table 2 Data collected from the sleep position trainer

	First week (diagnosis)	Last week	*p* value
Percentage of supine sleep	28.3 ± 18.2	13.1 ± 17.9	< 0.001
Number of turning to supine	13.4 ± 5.7	13.2 ± 6.2	0.111
Number of vibrations	27.3 ± 23.2	25.8 ± 27.5	0.122
Number of responses to vibrations	5.1 ± 3.5	5.3 ± 4.7	0.146
Response rate	27.4 ± 18.3	37.2 ± 33.4	0.337

Mean data over the nights the device was used

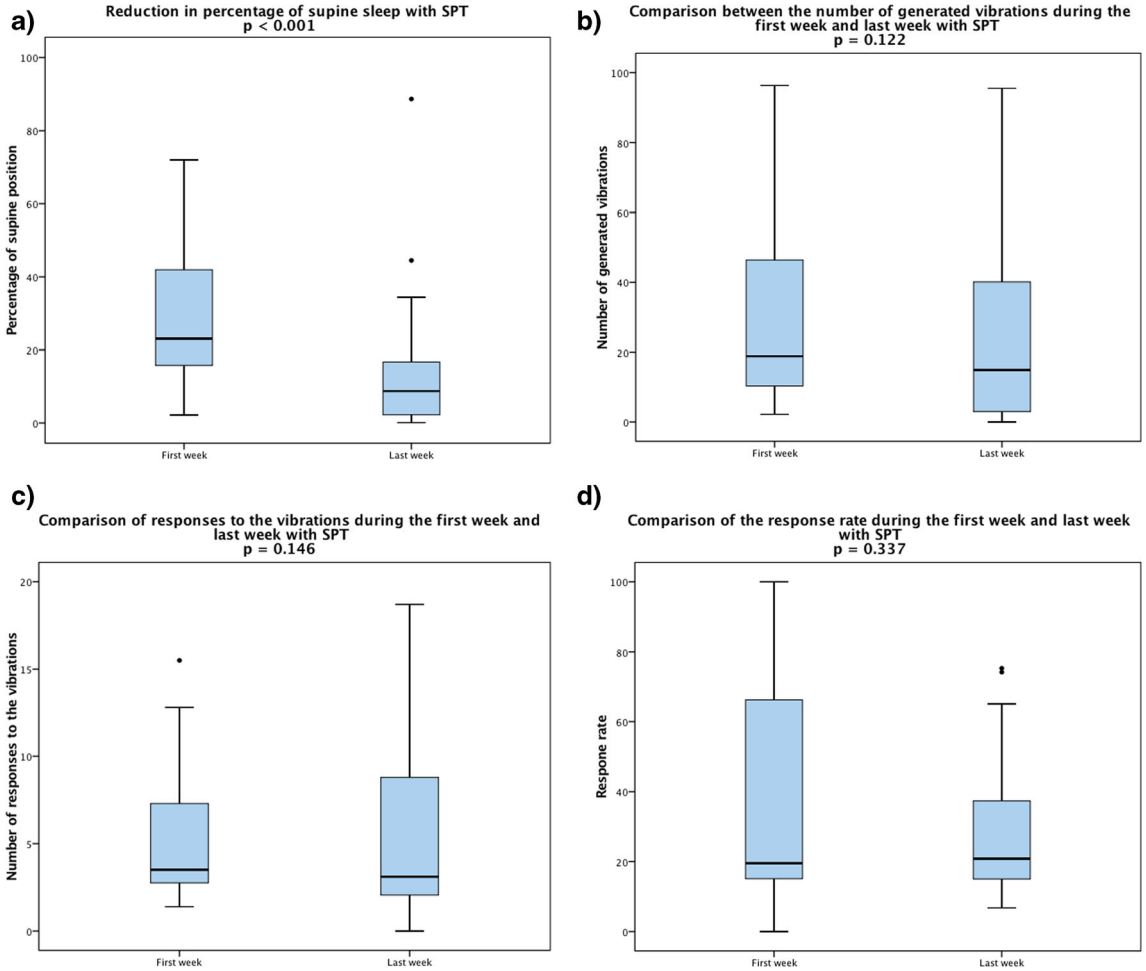

Fig. 4 Data collected from SPT during first and last week of use for **a** reduction in percentage of supine sleep, **b** number of vibrations generated, **c** responses to the vibrations, and **d** response percentage. SPT sleep position trainer

phenomenon was reported by Dieltjens et al. comparing self-reported and objective adherence in oral appliance therapy with a mean subjective overestimation of 30 min [31]. Such findings emphasize the necessity of the objective assessment

Table 3 Anthropometric and polysomnographic parameters at baseline and with SPT in patients with a complete data set ($n = 18$)

Characteristic	Baseline	With SPT	*p* value
Male/female, number			
Age, years	54.78 ± 7.58		
BMI, kg/m^2	28.0 (26.3; 29.2)	27.9 (26.1; 28.7)	0.585
AHI, events/h	14.1 (11.9; 23.8)	9.8 (3.1; 12.6)	0.004*
AHI supine, events/h	42.7 (24.5; 54.1)	0.0 (0; 5.7)	0.006*
AHI non-supine, events/h	5.3 (2.3; 8.2)	7.3 (2.6; 11.9)	0.085
Time spent in supine position, % TST	36.8 (18.1; 56.0)	0 (0; 40.85)	< 0.001*
ODI, events/h	5.00 (2.5; 10.5)	2.4 (0.7; 4.3)	0.008*
Mean SpO_2, %	94.7 (94.1; 95.5)	95.1 (94.7; 95.6)	0.154
Minimum SpO_2, %	85.0 (79.0; 88.0)	89.5 (84.0; 91.0)	0.205

Results in mean ± standard deviation, median (quartile 1; quartile 3)

SPT sleep position trainer, *BMI* body mass index, *AHI* apnea/hypopnea index, *TST* total sleep time, *ODI* oxygen desaturation index, *SpO_2* oxygen saturation

*statistically significant

$N = 18$

of adherence of device therapies when the effectiveness of different treatment modalities is compared.

A significant difference in the reduction of the percentage of supine sleep time was found between PSG and SPT. The SPT measured the percentage of supine sleep during the first and last week of SPT use at home, whereas the results with PSG are based on attended sleep studies during a single night in a hospital setting. This approach does not take into account the night-to-night variability, nor the difference in supine sleep time at home versus a hospital setting. Moreover, the reported percentage supine with SPT during the first includes the build-up phase of the SPT (from night 3 on). This could mean that the percentage of supine sleep could already be reduced during this first week of use, maybe also explaining the smaller reduction in percentage supine based on SPT data.

The main limitation of the study is that only patients interested in a follow-up PSG or out-patient visit were included, resulting in a rather small study population. In addition, a complete data set of only 18 patients could be collected. This requires some caution in the interpretation of the results. Further research in a larger study population is required to confirm the present results.

Conclusions

The findings of the present study confirm that the SPT can be used in a routine clinical practice setting for the treatment of POSA in well-selected OSA patients, which were mainly middle-aged, slightly overweight with moderate OSA. In this subgroup of OSA patients, the long-term use of an SPT reduced the percentage of supine sleep and overall AHI. An adherence rate of 69% at 1 year was reached in the group of continuing users (85%). Chronic use of the SPT device is favored if habituation to the vibrations is absent. However, habituation was only seen in the minority of the patients.

Acknowledgements The authors would like to thank Adelheidis Hoogewijs for her assistance with this research project.

Compliance with ethical standards

Conflict of interest Olivier Vanderveken holds a Senior Clinical Investigator Fellowship from the Research Foundation, Flanders (FWO), 2016-2021. Marijke Dieltjens holds a Postdoctoral fellowship at Research Foundation, Flanders (FWO), 12H4516N.

Dr. Vanderveken reports other from Research support from NightBalance, during the conduct of the study; grants from Philips research grant at Antwerp University Hospital, grants from Somnomed research grant at Antwerp University Hospital, other from Somnomed, other from Inspire Medical Systems, other from Galvani, other from Zephyr, outside the submitted work. Dr. Verbraecken reports grants from NightBalance, during the conduct of the study. Dr. Braem reports grants from Somnomed Research Grant, outside the submitted work.

Research involving human participants All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Abbreviations AHI, apnea/hypopnea index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness scale; ODI, oxygen desaturation index; OSA, obstructive sleep apnea; POSA, positional obstructive sleep apnea; PSG, polysomnography; PT, positional therapy; SDB, sleep-disordered breathing; SPT, sleep position trainer; SpO_2, minimum oxygen saturation; TST, total sleep time; VAS snoring, visual analogue scale for snoring

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

1. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S (1993) The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 328(17):1230–1235
2. Kryger MH (2000) Diagnosis and management of sleep apnea syndrome. Clin Cornerstone 2(5):39–47
3. Malhotra A, White DP (2002) Obstructive sleep apnoea. Lancet 360(9328):237–245
4. Dempsey JA, Veasey SC, Morgan BJ, O'Donnell CP (2010) Pathophysiology of sleep apnea. Physiol Rev 90(1):47–112
5. Jennum P, Kjellberg J (2011) Health, social and economical consequences of sleep-disordered breathing: a controlled national study. Thorax 66(7):560–566
6. (1999) Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force. Sleep 22(5): 667–89
7. Sullivan CE, Issa FG, Berthon-Jones M, Eves L (1981) Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. Lancet 1(8225):862–865
8. Epstein LJ, Kristo D, Strollo PJ Jr, Friedman N, Malhotra A, Patil SP, Ramar K, Rogers R, Schwab RJ, Weaver EM, Weinstein MD, Adult Obstructive M, Sleep Apnea Task Force of the American Academy of Sleep (2009) *Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults*. J Clin Sleep Med 5(3):263–276
9. Robinson GV, Stradling JR, Davies RJ (2004) Sleep . 6: obstructive sleep apnoea/hypopnoea syndrome and hypertension. Thorax 59(12):1089–1094
10. Grote L, Hedner J, Grunstein R, Kraiczi H (2000) Therapy with nCPAP: incomplete elimination of Sleep Related Breathing Disorder. Eur Respir J 16(5):921–927
11. Kribbs NB, Pack AI, Kline LR, Smith PL, Schwartz AR, Schubert NM, Redline S, Henry JN, Getsy JE, Dinges DF (1993) Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. Am Rev Respir Dis 147(4):887–895
12. Marklund M, Verbraecken J, Randerath W (2012) Non-CPAP therapies in obstructive sleep apnoea: mandibular advancement device therapy. Eur Respir J 39(5):1241–1247
13. Cartwright RD (1984) Effect of sleep position on sleep apnea severity. Sleep 7(2):110–114

14. Marklund M, Persson M, Franklin KA (1998) Treatment success with a mandibular advancement device is related to supine-dependent sleep apnea. Chest 114(6):1630–1635
15. Mador MJ, Kufel TJ, Magalang UJ, Rajesh SK, Watwe V, Grant BJ (2005) Prevalence of positional sleep apnea in patients undergoing polysomnography. Chest 128(4):2130–2137
16. Bignold JJ, Mercer JD, Antic NA, McEvoy RD, Catcheside PG (2011) Accurate position monitoring and improved supine-dependent obstructive sleep apnea with a new position recording and supine avoidance device. J Clin Sleep Med 7(4):376–383
17. Oksenberg A, Silverberg DS, Arons E, Radwan H (1997) Positional vs nonpositional obstructive sleep apnea patients: anthropomorphic, nocturnal polysomnographic, and multiple sleep latency test data. Chest 112(3):629–639
18. Richard W, Kox D, den Herder C, Laman M, van Tinteren H, de Vries N (2006) The role of sleep position in obstructive sleep apnea syndrome. Eur Arch Otorhinolaryngol 263(10):946–950
19. Eiseman NA, Westover MB, Ellenbogen JM, Bianchi MT (2012) The impact of body posture and sleep stages on sleep apnea severity in adults. J Clin Sleep Med 8(6):655–66A
20. Permut I, Diaz-Abad M, Chatila W, Crocetti J, Gaughan JP, D'Alonzo GE, Krachman SL (2010) Comparison of positional therapy to CPAP in patients with positional obstructive sleep apnea. J Clin Sleep Med 6(3):238–243
21. Oksenberg A, Silverberg D, Offenbach D, Arons E (2006) Positional therapy for obstructive sleep apnea patients: a 6-month follow-up study. Laryngoscope 116(11):1995–2000
22. Heinzer RC, Pellaton C, Rey V, Rossetti AO, Lecciso G, Haba-Rubio J, Tafti M, Lavigne G (2012) Positional therapy for obstructive sleep apnea: an objective measurement of patients' usage and efficacy at home. Sleep Med 13(4):425–428
23. Levendowski DJ, Seagraves S, Popovic D, Westbrook PR (2014) Assessment of a neck-based treatment and monitoring device for positional obstructive sleep apnea. J Clin Sleep Med 10(8):863–871
24. van Maanen JP, Meester KA, Dun LN, Koutsourelakis I, Witte BI, Laman DM, Hilgevoord AA, de Vries N (2013) The sleep position trainer: a new treatment for positional obstructive sleep apnoea. Sleep Breath 17(2):771–779
25. van Maanen JP, de Vries N (2014) Long-term effectiveness and compliance of positional therapy with the sleep position trainer in the treatment of positional obstructive sleep apnea syndrome. Sleep 37(7):1209–1215
26. Bignold JJ, Deans-Costi G, Goldsworthy MR, Robertson CA, McEvoy D, Catcheside PG, Mercer JD (2009) Poor long-term patient compliance with the tennis ball technique for treating positional obstructive sleep apnea. J Clin Sleep Med 5(5):428–430
27. Ravesloot MJL, White D, Heinzer R, Oksenberg A, Pepin JL (2017) Efficacy of the new generation of devices for positional therapy for patients with positional obstructive sleep apnea: a systematic review of the literature and meta-analysis. J Clin Sleep Med 13(6):813–824
28. Beyers J, Dieltjens M, Kastoer C, Opdebeeck L, Boudewyns AN, De Volder I, Van Gastel A, Verbraecken JA, De Backer WA, Braem MJ, Van de Heyning PH, Vanderveken OM (2018) Evaluation of a trial period with a sleep position trainer in patients with positional sleep apnea. J Clin Sleep Med 14:575–583
29. Iber C, Ancoli-Israel S, Chesson A, Quan S, f.t.A.A.o.S. Medicine (2007) The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications. American Academy of Sleep Medicine, Westchester
30. de Ruiter MHT, Benoist LBL, de Vries N, de Lange J (2017) Durability of treatment effects of the Sleep Position Trainer versus oral appliance therapy in positional OSA: 12-month follow-up of a randomized controlled trial. Sleep Breath
31. Dieltjens M, Braem MJ, Vroegop A, Wouters K, Verbraecken JA, De Backer WA, Van de Heyning PH, Vanderveken OM (2013) Objectively measured vs self-reported compliance during oral appliance therapy for sleep-disordered breathing. Chest 144(5):1495–1502