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Complete List of Authors:	Kelly, Julia; Guy's and St Thomas' NHS Foundation Trust, Royal Brompton Hospital; Imperial College London, National Heart and Lung Institute Turnbull, Chris; Oxford University Hospitals NHS Foundation Trust, Oxford Centre for Respiratory Medicine; University of Oxford, Nuffield Department of Medicine Newson, Roger; Queen Mary University of London, Wolfson Institute of Preventive Medicine Dobson, Melissa; Oxford Respiratory Trials Unit Hedley, Emma; Oxford Respiratory Trials Unit ALQarni, Abdullah; Imperial College London, National Heart and Lung Institute; Imam Abdulrahman Bin Faisal University, Respiratory Care Nevinson, Ann; Patient Representative Dawson, David; Bradford Teaching Hospitals NHS Foundation Trust Nickol, Annabel; Oxford University Hospital NHS Trust, Oxford Centre for Respiratory Medicine; University of Oxford, Department of Physiology, Anatomy and Genetics West, Sophie; Newcastle Upon Tyne Hospitals NHS Foundation Trust, Talbot, Nick; University of Oxford, Department of Physiology, Anatomy and Genetics; Oxford University Hospitals NHS Foundation Trust, Oxford Centre for Respiratory Medicine Rahman, Najib M.; University of Oxford, Oxford Respiratory Trials Unit; Chinese Academy of Medicine Oxford Institute Stradling, John; Oxford Centre for Respiratory Medicine, NIHR Biomedical Research Centre and Oxford University Morrell, Mary; Imperial College London, National Heart and Lung Institute
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Vibrotactile Positional Therapy for the treatment of positional obstructive sleep apnoea: a multicentre, randomised controlled trial

Authors (first name, last name, degrees and affiliations):

Julia L Kelly, PhD, Royal Brompton Hospital, Guy's and St Thomas' NHS Foundation Trust; National Heart and Lung Institute, Imperial College London, London, UK
Christopher D Turnbull, DPhil, Oxford NIHR Biomedical Research Centre, Oxford, UK
Roger Newson, DPhil, Wolfson Institute of Preventive Medicine, Queen Mary University of London, London, UK
Melissa Dobson, BSc (Hons), Oxford Respiratory Trials Unit, Oxford, UK
Emma L Hedley, (no degree), Oxford Respiratory Trials Unit, Oxford, UK
Abdullah S ALQarni, PhD, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia; National Heart and Lung Institute, Imperial College London, UK
Ann Nevinson, Patient Representative and Board Member Sleep Apnoea Trust Association, UK
David Dawson, FRCA, Bradford Teaching Hospitals NHS Foundation Trust, UK
Annabel H Nickol, PhD, Churchill Hospital, Oxford University Hospital NHS Foundation Trust, Hospital, Oxford, UK
Sophie West, MD, Freeman Hospital, The Newcastle Upon Tyne Hospitals NHS Foundation Trust, Newcastle, UK
Nick P Talbot, DPhil, Oxford University Hospital NHS Foundation Trust, Oxford, UK; Department of Physiology, Anatomy & Genetics, University of Oxford, UK
Najib M Rahman, DPhil, Oxford Respiratory Trials Unit,Oxford NIHR Biomedical Research Centre, Oxford, UK, Chinese Academy of Medicine Oxford Institute, Oxford, UK
John R Stradling, MD, Oxford NIHR Biomedical Research Centre, Oxford, UK
Mary J Morrell, PhD, National Heart and Lung Institute, Imperial College London, UK
on behalf of the POSA trial investigators*.

*Investigators are listed in the online supplement (Table s1)

Correspondence to: Julia Kelly. Sleep and Ventilation Department, Royal Brompton Hospital, Sydney Street, SW3 6NP. j.kelly@rbht.nhs.uk

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ABSTRACT

Background: New generation positional therapy devices provide vibrotactile feedback to patients with positional obstructive sleep apnoea (POSA), reducing supine sleep time and sleep apnoea severity. Longer-term effects on POSA severity, sleepiness and quality of life (QoL) are unclear.

Methods: A randomised, parallel, double-blinded trial compared neck-worn Positional Therapy with Sham-Positional Therapy over 3 months (ClinicalTrials.gov:NCT04153240).

Adult patients with POSA (apnoea/hypopnea index (AHI)>5 events/hour, 2:1 when supine versus non-supine) were randomised (1:1).

Primary endpoint was AHI at 3 months, Positional versus Sham. Secondary analyses: interaction between the treatment effect and age; QoL, including Epworth Sleepiness Scale (ESS) and Pittsburgh Sleep Quality Index (PSQI).

Results: Between Oct 2019 and Aug 2022, 120 patients with median baseline AHI of 12.8 events/hr (IQR 9.2, 18.5) were randomised; 59 to Positional Therapy and 61 to Sham; 92 (77%) completed the trial. Positional Therapy significantly reduced the AHI by -4.41 events/hr (95%CI -7.77, -1.06; p=0.011) compared to Sham, a 34% improvement. There was a significant improvement in PSQI: -1.0 (95%CI -2.1, 0.0; p=0.04), but not ESS: -0.6 (95%CI -1.8, 0.6; p=0.3), with Positional Therapy compared to Sham (baseline ESS 8.8). Similar results were seen in younger (18-64) and older (≥65) age groups. Patients' bed partners reported improvements in snoring, and sleep quality for the patient and themselves. Over half of participants using the active device opted to continue.

Conclusion: Neck-worn Positional Therapy reduced the severity of OSA and improved sleep quality but not sleepiness, over 3 months. Bed partner's reported improvements in snoring and sleep quality.

KEY MESSAGES

- **What is already known on this topic** -
  - Vibrotactile Positional Therapy has been shown to reduce disease severity in the short term; there is little evidence over longer term, particularly controlled studies for neck worn devices, which include quality-of-life outcomes.

- **What this study adds** -
  - Longer term neck-worn vibrotactile Positional Therapy significantly reduced the severity of sleep apnoea and improved sleep quality, but not sleepiness in patients with predominately mild-moderate positional obstructive sleep apnoea. Additionally, patients' bed partners reported improvements in snoring, and sleep quality for both the patient and themselves.

- **How this study might affect research, practice or policy** -
  - The results of the POSA trial support the expert consensus reported in the NICE NG202 recommendation: Vibrotactile Positional Therapy should be considered for people with mild or moderate POSA.

INTRODUCTION

Obstructive sleep apnoea (OSA) is a common disorder characterised by repetitive airway collapse during sleep. It has a prevalence of 5-10% across the global adult population[1], rising to 30% in older patients[2] due to age-related changes in the pharyngeal airway.[3-5]

Positional OSA (POSA), is a subset of OSA which either occurs exclusively, or is made worse by, the supine position. POSA is commonly defined as an apnoea-hypopnoea index (AHI) in the supine position that is twice that of the non-supine AHI,[6] and is present in between 50-75% of patients with OSA and in 53% of the general population.[7, 8]

Positional Therapy aims to discourage sleeping in the supine position, and thereby reduce or eliminate airway collapse.[9] UK guidelines recommend consideration of Positional Therapy for people with mild or moderate positional OSA if other treatments, such as continuous positive airway treatment (CPAP), are unsuitable or not tolerated.[10] Positional Therapy traditionally provided a physical barrier or deterrent to supine sleep. Although these interventions were effective at reducing AHI, poor comfort and intolerance combined with subsequent low long-term adherence rates meant that they were not adopted as standard practice.[11-13]

New generation vibrotactile devices use position sensors to determine patient position and haptic motors to deter the supine position by vibratory feedback stimulation. These devices are worn either on the neck, the forehead or the chest.[14-16] Systematic reviews and meta-analyses of the evidence for all vibrotactile Positional Therapy devices supports reduction in supine sleep time and in AHI.[17-19] Moreover, improved comfort and more promising adherence rates have been observed, compared to traditional methods.[20, 21]

The neck-worn vibrotactile Positional Therapy has been shown to reduce the severity of OSA in the short-term.[22-24] However, there are few data on the longer-term effects on sleep apnoea severity, limited information of the treatment effect on quality-of-life (QoL), and uncertainty on the effects in older individuals.[10, 19]. The POSA trial aimed to investigate longer-term effects of neck-worn Positional Therapy on OSA compared to a sham-control. The POSA trial also sought to investigate the effect of age on the efficacy of Positional Therapy, given the high prevalence of OSA in older patients.

METHODS

Study design and participants

The POSA trial was a multicentre, double-blind, parallel group, randomised controlled trial comparing Positional Therapy (Night Shift™; Advanced Brain Monitoring, USA) with Sham-Positional Therapy (see below Intervention and control), for 3 months in older (≥65 years) and younger patients (18 – <65 years). Recruitment was from six sleep centres by POSA trial investigators via the UK Respiratory Sleep Research Network (Supplement Tables s1 and s2). The trial was approved by a central ethics committee (REC-19/YH/0222, Yorkshire and the Humber – South Yorkshire) and all patients gave written informed consent. The trial was managed by the Trial Steering Committee and registered with ClinicalTrials.gov, NCT04153240.

Adult patients with suspected sleep apnoea were referred to their local sleep centre and assessed using local clinical management protocols. Patients with newly diagnosed POSA were invited to participate in the trial. Eligibility was confirmed by a home sleep test (respiratory polygraphy with automated scoring algorithm; Apnealink Air and Airview software, ResMed Ltd, Oxfordshire, UK) (See supplement section 2.2).

Inclusion criteria

Patients (≥18 years) were eligible to enter the trial if they had POSA, diagnosed as an overall AHI >5 events/hour (AASM 2012 scoring criteria) with events occurring at a frequency of 2:1 when supine,[6] compared to non-supine; a total percentage supine sleep time >10 and <90% of total sleep time; and if respiratory events were predominantly obstructive. Exclusion criteria in supplement section 2.3.

The full POSA protocol can be found on ClinicalTrials.gov: https://www.clinicaltrials.gov/study/NCT04153240.

Randomisation and masking

Eligible patients were randomly assigned (1:1) to Positional Therapy or Sham-Positional Therapy using an online computer-generated randomisation schedule (Registration/Randomisation and Management of Product), with minimisation based on age group (18-<65: ≥65 years), and OSA severity (AHI <20: ≥20 events/hr).

The Positional Therapy devices were pre-set by an unblinded researcher in the trial management team (AA) who was not involved in outcome assessments or patient visits. Devices were pre-set to either 'TRIAL', which was the intervention - first night monitoring, vibration feedback from second night onwards, or 'MONITOR', which was the control - monitoring only, no vibration feedback. They were subsequently labelled with a trial asset numbers according to a random number sequence provided by Oxford Respiratory Trials Unit (ORTU). Only the device numbers identified the allocation of each device. The participants, researchers, clinicians and trial statistician were blinded until after the data analysis was completed.

Procedures

Eligible patients attended two outpatient visits with their local sleep service, one at baseline and one at 3 months. At the baseline visit, patients provided demographic information, a medical hisotry, and

completed baseline QoL questionnaires. Patients also reported the symptoms leading to their referral. At the end of the baseline visit, patients were randomised.

Intervention and control

The vibrotactile Positional Therapy was delivered by the NightShift™ Sleep Positioner (Advanced Brain Monitoring, Carlsbad, USA) worn on the back of the neck (Figure 1). The active Positional Therapy vibrated when supine position was detected and increased in intensity until the participant changed position.

The Sham-Positional Therapy device provided monitoring only with no vibration feedback.

Follow-up

After 4 nights, participants in both groups were contacted by the central research team (Royal Brompton Hospital), by either phone call or email, to determine early patient experience and troubleshoot any issues that had arisen.

After 3 months of treatment, participants had further follow-up, repeating the baseline QoL questionnaires, and additionally completing questionnaires detailing their experience with the Positional Therapy device and, where applicable, their bed partner's experience (see supplement section 2.4). They also performed a follow-up home sleep test (Apnealink Air) with the Positional Therapy device in situ. Data from the Positional Therapy device, including adhrence, was downloaded via an internet-based Report Portal (Advanced Brain Monitoring, Carlsbad, USA). Participants in the active treatment group were asked if they wished to continue Positional Therapy and participants in the Sham group were offered Positional Therapy treatment.

During the first wave of the COVID pandemic in March 2020, the trial was paused and the trial protocol, by necessity, was amended to provide remote options for all patient interactions i.e. consent, trial visits and diagnostic sleep studies (see supplement section 2.5 and supplement Table s3).

Primary Outcome

AHI at 3 months, measured by a repeat home sleep test (polygraphy) with the Positional Therapy device *in situ*, adjusted for baseline AHI, and compared between Positional Therapy and Sham-Positional Therapy.

Secondary outcomes

The comparison of the treatment effect between older and younger participants was a secondary outcome. Other secondary outcomes included the percentage supine sleep time and oxygen desaturation index (ODI), plus participants' subjective symptoms, wellbeing and quality of life (QoL) which were assessed by questionnaires: Epworth Sleepiness Scale (ESS),[25] Functional Outcomes of Sleep Questionnaire (FOSQ),[26] Hospital Anxiety and Depression Scale (HADS),[27] Independent Functioning (Townsend Disability Scale),[28] ShortForm-36 (eight scales),[29] a Healthcare Utilisation Questionnaire, EuroQol EQ-5D,[30] and Pittsburgh Sleep Quality Index (PSQI).[31] Partners or carers' perspective was also captured. Adherence to therapy was measured by the Positional therapy device.

Sample Size

A sample size of 138 participants (69 per group) was estimated to detect a clinically important treatment difference (AHI of 5 events/hour at 3 months), powered to detect superiority of Positional Therapy compared to Sham at 90% power and 5% significance level, assuming within-group standard deviation of 9.05 events/hour, based on systematic review data.[17] Target recruitment was set at 155 patients to account for an assumed 10% drop-out rate.

Post Covid-19 pandemic, when recruitment rates were slower than expected (March 2022), the Trial Steering Committee decided to reduce the power of the study from 90 to 80% in line with previous UK sleep trials,[32, 33] thus reducing the sample size from 138 to 104 participants (52 per group). A new target recruitment was set at 116 patients.

Statistical analysis

Data are presented according to CONSORT guidelines. All primary analyses were performed on an intention-to-treat principle. Statistical analysis was done by independent statistician (blind to the which group was which) in accordance with a predefined analysis plan. All data were imported into Stata Version 17 for statistical analysis.

Analysis of the primary outcome was performed by linear regression of final AHI with respect to treatment, adjusting for baseline AHI and age group. All secondary data (objective sleep data and subjective quality of life data) were analysed in the same way. No formal adjustments for multiple significance testing were made.

The trial was analysed as a 2x2 factorial design. The comparison of primary interest was between patients of all ages randomised to the active treatment and patients of all ages allocated to the Sham treatment, and the old-young comparison is a matter of secondary analysis. The final AHI was used as the primary outcome and included age as a blocking factor as well as including baseline AHI as a linear predictor which acted to slim the confidence intervals and reduce bias caused by unfortunate randomisation. Age was used as a binary (older versus younger) variable rather than continuous as it was not certain that the effect of age was linear.

RESULTS

Between Oct 30th, 2019, and Aug 8th, 2022, 120 patients with POSA were recruited; 59 were randomised to Positional Therapy and 61 to Sham-Positional Therapy. Ninety-six participants (80%) were in the younger group (18 – <65 years), and 24 participants (20%) in the older group (≥65 years). Ninety-two participants (77%) completed the trial (Figure 2).

Baseline demographics and clinical characteristics are presented in Table 1. The mean age was 52.7 [standard deviation or SD 12.3] years; (younger group: 49 [SD 10] vs older group: 70 [SD 3.8] years). The baseline sleep study showed that participants had on average mild OSA (AHI of 12.8 events/hr (Interquartile range or IQR 9.2, 18.5)). Participants were on average not sleepy (ESS 8.8 points [SD 4.7]); however, they were poor sleepers as measured by the PSQI (9.0 points [SD 4.1]). Characteristics were similar between the groups.

Table 1: Baseline demographic and clinical characteristics of patients with positional obstructive sleep apnoea

	Positional Therapy: (n=59)	Sham-Positional Therapy: (n=61)	Total: (n=120)
Age (years)	53.6 (11.8)	51.8 (12.8)	52.7 (12.3)
Gender: n(%)			
Male	42 (71.2%)	52 (85.2%)	94 (78.3%)
Female	17 (28.8%)	9 (14.8%)	26 (21.7%)
BMI (kg/m^2)	28.3 (4.4)	28.4 (3.9)	28.4 (4.2)
Ethnicity: n(%)			
White	56 (94.9%)	54 (88.5%)	110 (91.7%)
Hispanic/Latino	1 (1.7%)	1 (1.6%)	2 (1.7%)
Asian (India/Pakistan/Bangladesh)	2 (3.4%)	3 (4.9%)	5 (4.2%)
Mixed/Other	0 (0.0%)	3 (4.9%)	3 (2.5%)
Neck Circumference (cm)	40.0 (3.8)	40.9 (3.1)	40.5 (3.4)
Smoking Status: n(%)			
Never smoked	30 (50.8%)	40 (65.6%)	70 (58.3%)
Ex-smoker	25 (42.4%)	18 (29.5%)	43 (35.8%)
Current smoker	4 (6.8%)	2 (3.3%)	6 (5.0%)
Missing	0 (0.0%)	1 (1.6%)	1 (0.8%)
Smoking (pack years)	12.8 (9.9)	8.7 (7.3)	11.2 (9.1)
Self-reported medical history: n(%)			
Coronary artery disease	5 (8.5%)	1 (1.6%)	6 (4.0%)
Hypertension	11 (18.6%)	18 (29.5%)	29 (24.2%)
Diabetes	4 (6.8%)	3 (4.9%)	7 (5.8%)
Anxiety	21 (35.6%)	12 (19.7%)	33 (27.5%)
Depression	18 (30.5%)	13 (21.3%)	31 (25.8%)
Insomnia	11 (18.6%)	13 (21.3%)	24 (20.0%)
Rhinitis/other nasal problem	18 (30.5%)	12 (19.7%)	30 (25.0%)
Stroke/TIA	2 (3.4%)	1 (1.6%)	3 (2.5%)
Sleep study results:			
AHI (events/hour)	12.5 (9.5, 17.8)	13.1 (8.6, 19.7)	12.8 (9.2, 18.5)
Supine AHI (events/hour)	22.1 (16.7, 32.0)	21.2 (13.9, 35.6)	21.9 (15.1, 34.2)
Non-supine AHI (events/hour)	3.8 (2.0, 6.4)	4.6 (2.3, 7.6)	4.4 (2.0, 7.2)
AI (events/hour)	2.9 (1.1, 5.5)	2.1 (0.7, 6.2)	2.3 (0.8, 6.0)
HI (events/hour)	9.6 (7.0, 11.6)	8.9 (6.6, 14.1)	9.3 (6.7, 12.9)
ODI >3% (events/hour)	15.2 (10.7, 20.1)	16.0 (9.8, 21.5)	15.6 (10.1, 20.9)

Supine %TST (%)	53.2 (33.9, 62.2)	46.1 (36.7, 69.4)	49.5 (34.9, 65.8)
Randomisation OSA severity: n(%)			
AHI <20 (events/hour)	48 (81.4%)	47 (77.0%)	95 (79.2%)
AHI ≥20 (events/hour)	11 (18.6%)	14 (23.0%)	25 (20.8%)
Main reason for referral: n(%)			
Snoring	14 (23.7%)	19 (31.1%)	33 (27.5%)
Witnessed apnoea	19 (32.2%)	13 (21.3%)	32 (26.7%)
Unrefreshing Sleep	8 (13.6%)	5 (8.2%)	13 (10.8%)
Fatigue	5 (8.5%)	7 (11.5%)	12 (10.0%)
Excessive Daytime sleepiness	2 (3.4%)	7 (11.5%)	9 (7.5%)
Screening (pre-op or due to co-morbidity e.g. resistant hypertension)	4 (6.8%)	3 (4.9%)	7 (5.8%)
Poor memory/concentration	0 (0.0%)	1 (1.6%)	1 (0.8%)
Other	7 (11.9%)	6 (9.8%)	13 (10.8%)
Main driver for referral: n(%)			
Patient	24 (40.7%)	24 (39.3%)	47 (39.2%)
Bed-partner	20 (33.9%)	23 (37.7%)	43 (35.8%)
Respiratory Physician	4 (6.8%)	5 (8.2%)	9 (7.5%)
Cardiologist	5 (8.5%)	3 (4.9%)	8 (6.7%)
GP	5 (8.5%)	2 (3.3%)	7 (5.8%)
Other medical specialist	1 (1.7%)	4 (6.4%)	5 (4.0%)
Missing	1 (1.7%)	0 (0.0%)	1 (0.8%)
Quality of Life: mean higher scores means better status			
SF-36			
physical functioning	78.6 (24.8)	78.3 (27.3)	78.5 (25.9)
role limitations due to physical health	61.2 (38.4)	67.2 (40.1)	64.2 (39.2)
Role limitations due to emotional problems	66.7 (41.4)	69.0 (40.4)	67.8 (40.8)
energy/fatigue	43.9 (23.6)	44.4 (20.4)	44.2 (21.9)
emotional well-being	68.8 (21.5)	69.4 (18.1)	69.1 (19.8)
social functioning	69.4 (29.2)	76.9 (26.5)	73.3 (28.0)
pain	66.9 (26.0)	72.9 (25.3)	69.9 (25.7)
general health	52.5 (22.0)	56.6 (20.3)	54.5 (21.2)
FOSQ	16.8 (3.0)	16.7 (3.0)	16.7 (3.0)
general productivity	3.5 (0.6)	3.5 (0.6)	3.5 (0.6)
social outcome	3.6 (0.7)	3.6 (0.7)	3.6 (0.7)
activity level	3.1 (0.7)	3.1 (0.7)	3.1 (0.7)
vigilance	3.4 (0.7)	3.3 (0.6)	3.3 (0.7)
intimate activity	3.2 (0.9)	3.3 (0.8)	3.3 (0.9)
EQ-5D-5L TTO	0.8 (0.2)	0.8 (0.2)	0.8 (0.2)
EQ-5D-5L (VAS)	72.4 (17.6)	72.6 (17.5)	72.5 (17.5)
Quality of Life: mean lower scores means better status			
ESS	8.5 (4.4)	9.0 (5.0)	8.8 (4.7)
HADS (anxiety)	6.8 (4.8)	7.4 (4.7)	7.1 (4.7)
HADS (depression)	5.8 (4.4)	5.0 (4.3)	5.4 (4.3)
Townsend Disability Index	2.7 (4.6)	3.5 (6.1)	3.1 (5.4)
PSQI global score	8.5 (4.3)	9.4 (4.0)	9.0 (4.1)

Data presented as mean (SD), n (%) or median (IQR). BMI=Body mass index, TIA=transient ischaemic attack, AHI=apnoea-hypopnoea index, AI=apnoea index, HI=hypopnoea index, ODI=oxygen desaturation index,

TST=total sleep time, GP=general practitioner, SF-36=Short form-36, FOSQ=Functional Outcomes of Sleep Questionnaire, EQ-5D-5L=European QoL five dimensions Questionnaire, VAS=Visual Analogue Scale, ESS=Epworth Sleepiness Scale, HADS= Hospital Anxiety and Depression Scale, PSQI=Pittsburgh Sleep Quality Index.

Outcomes:

Severity of OSA

Positional Therapy significantly reduced the primary outcome of AHI by -4.4 events/hr (95% confidence interval or 95% CI -7.8, -1.1), p=0.011, a 34% improvement (Figure 3). As expected, the reduction in AHI was matched by a reduction in the percentage supine sleep time of -14.5% (95% CI -23.8, -5.2), p=0.003. Other sleep study parameters are presented in Table 2.

Table 2: Sleep study parameters in patients with positional obstructive sleep apnoea after 3 months of Positional Therapy versus Sham-Positional Therapy

Outcome at 3 months	Positional Therapy (n= 45)	Sham-Positional Therapy (n= 47)	Treatment difference (95% CI)	P value
AHI (events/hr)	5.2 (2.3, 11.2)	10.3 (6.2, 17.4)	-4.4 (-7.8, 1.1)	.011
Supine AHI (events/hr)	5.7 (1.6, 13.5)	18.0 (10.2, 27.8)	-8.6 (-14.2, -2.9)	.0034
Non-supine AHI (events/hr)	4.8 (2.3, 9.6)	3.6 (1.3, 5.7)	1.6 (-0.9, 4.0)	.2
AI (events/hr)	0.7 (0.2, 2.2)	1.3 (0.4, 3.2)	-1.5 (-3.3, 0.2)	.076
HI (events/hr)	4.6 (1.9, 6.9)	7.9 (4.3, 12.7)	-2.8 (-5.5, -0.1)	.039
ODI (events/hr)	8.5 (5.4, 12.2)	13.9 (9.0, 20.3)	-5.0 (-9.1, -0.9)	.017
Supine Percentage TST(%)	21.6 (7.7, 51.4)	41.4 (24.9, 63.8)	-14.5 (-23.8, -5.2)	.0027

Data presented as median (IQR) and mean treatment difference (95% CI). AHI=apnoea-hypopnoea index, AI=apnoea index, HI=hypopnoea index, ODI=oxygen desaturation index, TST=total sleep time.

Quality of life and sleepiness

There was a significantly greater improvement in sleep quality (PSQI: mean treatment difference -1.05 points (95%CI -2.07, -0.03), p=0.04), as well as the SF-36 emotional wellbeing score (mean treatment difference +7.01 points (95% CI +0.90, +13.12,), p=0.03) with Positional Therapy compared with Sham-Positional Therapy at 3 months. There were no other significant differences in sleepiness or other QOL scores between Positional Therapy and Sham-Positional Therapy (Table 3).

Table 3: Quality of Life in patients with positional obstructive sleep apnoea after 3 months of Positional Therapy versus Sham-Positional Therapy. N1 and N2 who completed each questionnaire in the Positional Therapy and Sham-Positional Therapy groups respectively.

Outcome at 3 months	N1, N2	Positional Therapy	Sham-Positional Therapy	Treatment difference (95% CI)	P value
Quality of Life: higher scores means better status					
SF-36					
Physical functioning	45, 44	75.4 (29.7)	75.1 (28.3)	-2.5 (-9.1, 4.1)	0.45
Role limitations due to physical health	44, 43	69.3 (38.2)	62.5 (44.3)	3.4 (-9.4, 16.2)	0.6

Role limitations due to emotional problems	44, 43	81.1 (34.0)	72.5 (41.2)	5.8 (-7.0, 18.6)	0.37
Energy/fatigue	41, 40	50.2 (24.9)	47.3 (24.0)	2.34 (-4.5, 9.2)	0.5
Emotional well-being	44, 43	71.6 (23.1)	66.4 (25.6)	7.0 (0.9, 13.1)	0.025
Social functioning	41, 43	78.7 (27.7)	72.6 (28.0)	7.4 (-1.5, 16.3)	0.1
Pain	44, 43	68.4 (25.8)	69.4 (26.3)	1.7 (-5.5, 8.8)	0.65
General health	44, 41	52.8 (22.1)	52.4 (23.2)	0.2 (-5.9, 6.3)	0.94
FOSQ	43, 46	17.1 (2.9)	16.3 (3.5)	0.6 (-0.3, 1.4)	0.2
General productivity	43, 46	3.6 (0.5)	3.5 (0.6)	0.1 (-0.1, 0.3)	0.18
Social outcome	42, 46	3.6 (0.6)	3.4 (0.8)	0.2 (-0.1, 0.4)	0.15
Activity level	43, 46	3.3 (0.7)	3.0 (0.8)	0.2 (0.0, 0.4)	0.11
Vigilance	43, 46	3.5 (0.6)	3.3 (0.7)	0.1 (-0.1, 0.3)	0.31
intimate activity	33, 38	3.2 (1.0)	3.2 (0.1)	0.0 (-0.3, 0.3)	0.99
EQ-5D-5L - Your health today	45, 44	71.1 (19.8)	70.5 (20.9)	-2.2 (-7.6,3.2)	0.42
EQ-5D-5L TTO score	45, 43	0.8 (0.3)	0.8 (0.3)	0.0 (-0.0, 0.1)	0.62
Quality of Life: lower scores means better status					
Epworth Sleepiness Scale	40, 44	7.8 (4.6)	9.0 (5.0)	-0.6 (-1.8, 0.6)	0.3
HADS anxiety score	59, 61	4.6 (4.9)	5.2 (6.0)	-0.6 (-2.1, 0.9)	0.44
HADS depression score	59, 61	3.9 (4.8)	3.8 (4.6)	-0.5 (-1.7, 0.7)	0.42
Townsend Disability Index	41, 38	2.5 (4.7)	2.5 (4.9)	0.4 (-1.6, 2.4)	0.68
PSQI global score	35, 35	7.5 (3.7)	9.1 (4.7)	-1.0 (-2.1, 0.0)	0.044

Data presented as mean (SD) and mean treatment difference (95% CI). SF-36=Short form-36, FOSQ=Functional Outcomes of Sleep Questionnaire, EQ-5D-5L=European QoL five dimensions Questionnaire, VAS=Visual Analogue Scale, ESS=Epworth Sleepiness Scale, HADS= Hospital Anxiety and Depression Scale, PSQI=Pittsburgh Sleep Quality Index.

Overall, when asked about their experience, 66% of participants in the Positional Therapy group reported a subjective improvement in their symptoms, compared to 22% in the Sham group. Fifty eight percent in the active group and 34% in the Sham group wished to continue positional therapy (Supplement Table s4).

Effect of age on the efficacy of Positional Therapy

Analyses combining age groups and adjusted for age group, were repeated separately for the two age groups (18-<65: ≥65 years) (Supplement Tables s5 and s6). Beneficial effects of Positional Therapy was observed for both groups, however, it should be noted that a relavtively small percentage (20%) of patients were aged 65+, and therefore the confidence intervals for the treatment effects in age group 65+ were wider than in the main combined-age analyses.

Bed partners' perspectives

Approximately three quarters of the 92 completers (72%) had a bed partner during the study (Supplement Table s7). Bed partners of those participants receiving Positional Therapy were more likely to report an improvement in snoring compared to the bed partners of those receiving Sham Positional Therapy (63% vs 24%). Likewise, the partners of those receiving Positional Therapy were also more likely to report improvements in sleep quality for both the participant (66% vs 9%) and themselves (50% vs 9%).

Adherence with Positional Therapy and side effects

Adherence data was available for 38 of 45 completers (84%) randomised to Positional Therapy, and 35 of 47 completers (74%) randomised to Sham-Positional Therapy (Supplement Table s8). The median

nights used in the 90-day period were 66 nights (IQR 49, 85) versus 68 nights (IQR 23, 85) respectively. The median nightly use over 90 days was 5:00 hrs (IQR 2:49, 6:13) versus 5:26 hrs (IQR 2:00, 6:25).

Participants reported being aware of the vibrational feedback in 96% of those receiving Positional Therapy versus 3% of those receiving Sham. Typically, those receiving Positional Therapy were aware of the feedback a median of 3 times (IQR 2,4) per night (Supplement Table s4).

Side effects were reported by 39 of 45 completers (87%) randomised to Positional Therapy, and 36 of 47 completers (77%) randomised to Sham-Positional Therapy (Supplement Table s9). The main side effects were strap/device discomfort (n=42), wakening due to vibrational feedback (n=21), continued snoring (n=17), position discomfort in non-supine positions (n=17), and continued symptoms (n=10). All reports of wakening due to vibrational feedback were made by those receiving Positional Therapy. Additionally, position discomfort due to sleeping in non-supine positions was reported more frequently by those receiving Positional Therapy compared to Sham-Positional Therapy (n=13 vs n=4 respectively). Continued symptoms were only reported in the Sham group (n=10).

Post-hoc analysis:

Comparison of responders and non-responders

In a post-hoc analysis, responders were defined as those whose AHI was reduced by ≥5 events/hr. There were 31 of 45 (69%) responders receiving Positional Therapy, compared to 16 of 47 (34%) of those receiving Sham-Positional Therapy.

In the Positional Therapy group (n=45), the responders when compared to the non- responders tended to have a higher baseline median percentage supine sleep time (51% (IQR 36,62) vs 33% (23, 80)), AHI (13 events/hr (IQR 11, 22) vs 9 events/hr (IQR 6, 18)) and ODI (16events/hr (IQR 12, 23) vs 11 events/hr (IQR 7, 21)) at baseline (Supplement Table s10). Responders were also more likely to report snoring as their reason for referral, when compared to non-responders (32 % vs 0%), while non-responders reported higher levels of witnessed apnoeas (43% v 29%).

Sensitivity analysis

Of the 120 participants randomised, 92 (77%) had measurements in the primary outcome (AHI) both at baseline and at 3 months. Due to possible bias caused by more dropouts than anticipated, these compliant participants may possibly have been unrepresentative of the intended-to-treat population. Therefore, a post-hoc sensitivity analysis was conducted using a completedness-propensity weighed analysis[34] for the treatment difference for AHI (Supplement section 3.6). Baseline covariates of age, pre-randomisation GP visits, and pre-randomisation days off work predicted AHI-completeness (supplement Table s11 and Figure s1). The sensitivity analysisprovided similar estimates to our main analysis with a treatment difference for the AHI of -4.1 events/ hr (95%CI -7.6, -0.7, p=0.02) between the groups.

DISCUSSION

The results of the POSA trial showed that neck-worn vibrotactile Positional Therapy, significantly reduced sleep apnoea severity, compared to sham, over a 3-month period. This was accompanied by an improvement in subjective sleep quality, but not in sleepiness. Similar results were seen in both younger (18-<65) and older (≥65) age groups. Additionally, patients' bed partners reported improvements in snoring, and sleep quality for the patient and themselves. Over half of participants using Positional Therapy opted to continue the therapy.

The reduction in AHI in the POSA trial is in keeping with previous data included in a recent meta-analysis of vibrotactile Positional Therapy.[18] This analysis found a significant reduction in AHI at follow-up, compared with baseline (mean difference (95% CI) –5.09 of events/hour (–7.37 to –2.81);p<0.00001). However, the majority of the RCTs included in this analysis differed from the POSA study; they used chest or forehead-worn devices, did not use a sham control, and had short follow-up periods (between one night to 8 weeks). One RCT has used a sham control device; this study tested a forehead-worn vibrotactile device over 12 weeks and found a significant reduction in AHI and supine sleep time in participants with on average severe OSA. [35] The study also reported on sleepiness, but only used a single QoL question (EuroQol VAS).

The POSA trial showed a modest effect with neck-worn vibrotactile Positional Therapy, compared to the published results for forehead-worn Positional Therapy. This may have occurred because the participants in the POSA trial had mild OSA which may have limited the treatment effect. The reduction in AHI in the POSA trial is less than the minimum important clinical difference (MICD) of 5 events/hour[36]. However, it is notable that the MICD for AHI was determined across all OSA severities and may be less relevant to those with mild OSA. Moreover, in the POSA trial over two thirds of participants responded to Positional Therapy based on achieving an AHI reduction ≥5 events/hr.

The prevalence of OSA is increased in older people[2] and the age-related increased collapsibility of the upper airway[3-5] may be more, or less, amenable to positional changes. The effect of Positional Therapy has not been specifically investigated in older individuals. The results of the POSA trial showed that age did not influence the effect of neck-worn vibrotactile Positional Therapy, and therefore it should be considered as a treatment in this population, although the confidence limits for age group over 65 were wider due to a small number of participants.

The POSA trial aimed to determine the effect of Positional Therapy on daytime sleepiness and QoL. Patient reported outcomes for OSA frequently focus on sleepiness measured using the ESS. In the POSA trial, the ESS was reduced post-treatment in both groups, with a non-significant mean treatment difference of less than one point. Low levels of baseline sleepiness may have limited any treatment effect. In other studies, small but consistent reductions in daytime sleepiness have been reported in response to Positional Therapy.[10, 18, 19] These reductions do not meet the MICD of between 2 and 3 points.[37] Taken together with the results of POSA trial, there is no overall meaningful change in daytime sleepiness with vibrotactile Positional Therapy.

The SF-36 questionnaire, specifically the Energy and Vitality subscale, has previously been used to show treatment related improvements in patients with OSA.[32, 33] Although Energy/Fatigue improved after 3 months in the POSA trial, there was no difference between the groups.

Sleep quality improved in the POSA trial, when measured by the PSQI scores. However, the mean 3-month scores remained over 5 points, which is the threshold for poor sleepers.[31] Sleep quality might have been affected by the use of vibrotactile stimuli which can cause arousal or awakening and thus lead to sleep fragmentation. However, participants reported being aware of the vibrations on average only 3 times a night. Side effects reported by those receiving active Positional Therapy included waking due to the vibrational feedback and positional discomfort due to sleeping in non-supine positions, whereas participants receiving Sham-Positional Therapy were more likely to report ongoing symptoms. Despite these side effects, participants on active Positional Therapy, were more likely to report improvement in their overall subjective symptoms (66% vs 22%) and were more likely to wish to continue the therapy (58% vs 34%) compared those participants receiving Sham. Overall, the neck

worn device was well tolerated without detriment to sleep quality, even leading to improved subjective sleep quality.

Bed partners of patients with OSA also experience benefits to their own sleep quality and daytime functioning following treatment.[38, 39] Improvements in relationships have also previously been reported with CPAP therapy.[39] In the POSA trial, the bed partners of those participants receiving neck-worn vibrotactile Positional Therapy were over twice as likely to report an improvement in snoring, and were more likely to report improvements in sleep quality for both the participant and themselves.

Therapy Adherence

In the POSA trial, adherence data was available in 84% of patients randomised to Positional Therapy and showed good overall levels of adherence. The median nightly use over 90 days was 5:00 hrs (IQR 2:49, 6:13) which is greater than the often quoted 4-hour recommended dose for CPAP treatment. Additionally, there were high levels of adherence to the Sham-Positional Therapy, suggesting that even without therapeutic benefit, the device was well tolerated. Other studies have also suggested improved levels of adherence in vibrotactile Positional Therapy and compared to traditional methods.[20, 21] Moreover, the adherence to vibrotactile Positional Therapy was greater than adherence to CPAP therapy, when directly compared.[40]

Limitations

The generalisability of the POSA trial results may be limited due to several factors. A low symptom burden in the POSA trial cohort could reduce the application of the findings, and may have represented referral bias, with those who were more symptomatic being referred straight for CPAP therapy. Participants reported on average normal daytime sleepiness and levels of anxiety and depression. There were also high numbers of Caucasian and male participants limiting the generalisability of the findings across race and sex. Few female participants made any potential sex comparisons underpowered.

Importantly, unselected POSA patients were recruited, without an upper limit AHI (i.e. not only mild and moderate OSA) and there was no specific targeting of those with exclusive positional dependence (i.e. those whose AHI was <10 events/hr in non-supine).[41, 42] This is likely to have limited the response in AHI reduction. The modest reduction in supine sleep time of 14% may also have affected the reduction in AHI. However, care must be taken when comparing with other trials as there is no standardised measurement of supine, with position measurements arising from either sleep testing devices, or indeed the Positional Therapy devices themselves. The method of measurement of sleep position may be a confounding factor because the head/ neck position has been shown to influence the AHI, independently of trunk position.[43]

Blinding patients in device trials is challenging, particularly when the device that is designed to provoke a response, i.e. a change in body position in response to a vibration on the neck. We chose an objective primary outcome of the POSA trial, the AHI, to minimise any effect should participants become unblinded.The trial was conducted during the Covid-19 pandemic which affected both the recruitment rate and the need to deliver the protocol remotely. While some participants were grateful for the remote diagnosis and management options, there were several barriers e.g. equipment and questionnaires needed posting during office hours. Ongoing staff redeployments also meant that research time was limited, and lead to frequent and multiple staffing changeovers, with unfortunate detrimental effects to follow-up and missing data. On the other hand, online information in the format

of YouTube videos, and online conversations were extremely useful, especially with respect to the use of a new treatment.

Conclusions

Neck-worn vibrotactile Positional Therapy reduces OSA severity in patients with POSA over three months. Taken together with the reports from bed partners, the vibrotactile Positional Therapy is also an effective treatment for sleep quality, despite only a small, non-significant improvement in some daytime symptoms in this minimally symptomatic group. Further research is now justified in a more symptomatic group with POSA.

a. Contributorship: All authors (except MD, ASA, DD, NMR) were members of the Trial Steering Committee with responsibility for the progress and conduct of the trial. JLK, CDT, JRS and MM were involved in the study conceptualisation and design, analysis of data, and all aspects of writing the manuscript. JK had responsibility for oversight of the trial, and is first author of the report. RN, statistician for POSA, had specific responsibility for the statistical analysis of the trial. AN was the patient representative. ELH was trial manager for POSA with specific responsibility for all aspects of data collection and recording, plus governance of the trial. MD and NMR were responsible for the governance of the trial. JRS was a senior investigator for POSA with specific responsibility for clinical oversight of the trial. MJM was principal investigator for POSA and has last authorship. All authors reviewed the manuscript. JLK was corresponding author and guarantor with the final responsibility to submit for publication.

b. Funding Statement: This project is funded by the National Institute for Health and Care Research (NIHR) under its Research for Patient Benefit (RfPB) Programme (Grant Reference Number PB-PG-0817-20049). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care.

c. Competing of Interests: none

d. Ethics approval: The trial was approved by a central ethics committee (REC-19/YH/0222, Yorkshire and the Humber – South Yorkshire)

e. Data sharing: Anonymised data may be provided upon reasonable request within the scope of the ethical committee approval.

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g. AI use statement: No AI or AI-assisted technologies were used in the preparation of this work.

REFERENCES:

1. Benjafield AV, Ayas NT, Eastwood PR, Heinzer R, Ip MSM, Morrell MJ, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. Lancet Respir Med. 2019;7(8):687-98.
2. McMillan A, Morrell MJ. Sleep disordered breathing at the extremes of age: the elderly. Breathe (Sheff). 2016;12(1):50-60.
3. Edwards BA, O'Driscoll DM, Ali A, Jordan AS, Trinder J, Malhotra A. Aging and sleep: physiology and pathophysiology. Semin Respir Crit Care Med. 2010;31(5):618-33.
4. Eikermann M, Jordan AS, Chamberlin NL, Gautam S, Wellman A, Lo YL, et al. The influence of aging on pharyngeal collapsibility during sleep. Chest. 2007;131(6):1702-9.
5. Malhotra A, Huang Y, Fogel R, Lazic S, Pillar G, Jakab M, et al. Aging influences on pharyngeal anatomy and physiology: the predisposition to pharyngeal collapse. Am J Med. 2006;119(1):72 e9-14.
6. Cartwright RD. Effect of sleep position on sleep apnea severity. Sleep. 1984;7(2):110-4.
7. Heinzer R, Petitpierre NJ, Marti-Soler H, Haba-Rubio J. Prevalence and characteristics of positional sleep apnea in the HypnoLaus population-based cohort. Sleep Med. 2018;48:157-62.
8. Joosten SA, O'Driscoll DM, Berger PJ, Hamilton GS. Supine position related obstructive sleep apnea in adults: pathogenesis and treatment. Sleep Med Rev. 2014;18(1):7-17.
9. Yingjuan M, Siang WH, Leong Alvin TK, Poh HP. Positional Therapy for Positional Obstructive Sleep Apnea. Sleep Med Clin. 2019;14(1):119-33.
10. NICE. Obstructive sleep apnoea/hypopnoea syndrome and obesity hypoventilation syndrome in over 16s. National Institute for Health and Clinical Excellence; 2021.
11. Bignold JJ, Deans-Costi G, Goldsworthy MR, Robertson CA, McEvoy D, Catcheside PG, et al. Poor long-term patient compliance with the tennis ball technique for treating positional obstructive sleep apnea. J Clin Sleep Med. 2009;5(5):428-30.
12. Oksenberg A, Silverberg D, Offenbach D, Arons E. Positional therapy for obstructive sleep apnea patients: A 6-month follow-up study. Laryngoscope. 2006;116(11):1995-2000.
13. Ravesloot MJ, van Maanen JP, Dun L, de Vries N. The undervalued potential of positional therapy in position-dependent snoring and obstructive sleep apnea-a review of the literature. Sleep Breath. 2013;17(1):39-49.
14. Levendowski DJ, Seagraves S, Popovic D, Westbrook PR. Assessment of a neck-based treatment and monitoring device for positional obstructive sleep apnea. J Clin Sleep Med. 2014;10(8):863-71.
15. van Maanen JP, Richard W, Van Kesteren ER, Ravesloot MJ, Laman DM, Hilgevoord AA, et al. Evaluation of a new simple treatment for positional sleep apnoea patients. J Sleep Res. 2012;21(3):322-9.
16. Hidalgo Armas L, Turino C, Cordero-Guevara J, Manjón JL, Durán-Carro J, Barbé F, et al. A new postural device for the treatment of positional obstructive sleep apnea. A pilot study. Respir Med. 2019;151:111-7.
17. Ravesloot MJL, White D, Heinzer R, Oksenberg A, Pepin JL. 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. 2017;13(6):813-24.
18. ALQarni AS, Turnbull CD, Morrell MJ, Kelly JL. Efficacy of vibrotactile positional therapy devices on patients with positional obstructive sleep apnoea: a systematic review and meta-analysis. Thorax. 2023.
19. Srijithesh PR, Aghoram R, Goel A, Dhanya J. Positional therapy for obstructive sleep apnoea. Cochrane Database Syst Rev. 2019;5:CD010990.

20. Hidalgo-Armas L, Inglés S, Vaca R, Cordero-Guevara J, Durán-Carro J, Ullate J, et al. Patient compliance and satisfaction with a new forehead device for positional obstructive sleep apnoea treatment: a post hoc analysis of a randomised controlled trial. BMJ Open Respir Res. 2023;10(1).
21. Laub RR, Tønnesen P, Jennum PJ. A Sleep Position Trainer for positional sleep apnea: a randomized, controlled trial. J Sleep Res. 2017;26(5):641-50.
22. Scarlata S, Rossi Bartoli I, Santangelo S, Giannunzio G, Pedone C, Antonelli Incalzi R. Short-term effects of a vibrotactile neck-based treatment device for positional obstructive sleep apnea: preliminary data on tolerability and efficacy. J Thorac Dis. 2016;8(7):1820-4.
23. Mok Y, Tan A, Hsu PP, Seow A, Chan YH, Wong HS, et al. Comparing treatment effects of a convenient vibratory positional device to CPAP in positional OSA: a crossover randomised controlled trial. Thorax. 2020;75(4):331-7.
24. Suzuki M, Funayama Y, Homma M, Shibasaki K, Furukawa T, Yosizawa T. Effect of position therapy and oral devices on sleep parameters in patients with obstructive sleep apnea. Eur Arch Otorhinolaryngol. 2021;278(11):4545-50.
25. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep. 1991;14(6):540-5.
26. Weaver TE, Laizner AM, Evans LK, Maislin G, Chugh DK, Lyon K, et al. An instrument to measure functional status outcomes for disorders of excessive sleepiness. Sleep. 1997;20(10):835-43.
27. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand. 1983;67(6):361-70.
28. Townsend P. Poverty in the United Kingdom. Harmondsworth: Pelican; 1979.
29. Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care. 1992;30(6):473-83.
30. Thorn JC, Brookes ST, Ridyard C, Riley R, Hughes DA, Wordsworth S, et al. Core Items for a Standardized Resource Use Measure (ISRUM): Expert Delphi Consensus Survey. Value in Health. 2017.
31. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res. 1989;28(2):193-213.
32. Wimms AJ, Kelly JL, Turnbull CD, McMillan A, Craig SE, O'Reilly JF, et al. Continuous positive airway pressure versus standard care for the treatment of people with mild obstructive sleep apnoea (MERGE): a multicentre, randomised controlled trial. Lancet Respir Med. 2020;8(4):349-58.
33. Craig SE, Kohler M, Nicoll D, Bratton DJ, Nunn A, Davies R, et al. Continuous positive airway pressure improves sleepiness but not calculated vascular risk in patients with minimally symptomatic obstructive sleep apnoea: the MOSAIC randomised controlled trial. Thorax. 2012;67(12):1090-6.
34. Seaman SR, White IR. Review of inverse probability weighting for dealing with missing data. Stat Methods Med Res. 2013;22(3):278-95.
35. Hidalgo Armas L, Ingles S, Vaca R, Cordero-Guevara J, Duran Carro J, Ullate J, et al. New forehead device in positional obstructive sleep apnoea: a randomised clinical trial. Thorax. 2021;76(9):930-8.
36. Emami E, Heydecke G, Rompré PH, de Grandmont P, Feine JS. Impact of implant support for mandibular dentures on satisfaction, oral and general health-related quality of life: a meta-analysis of randomized-controlled trials. Clin Oral Implants Res. 2009;20(6):533-44.
37. Patel S, Kon SSC, Nolan CM, Barker RE, Simonds AK, Morrell MJ, et al. The Epworth Sleepiness Scale: Minimum Clinically Important Difference in Obstructive Sleep Apnea. Am J Respir Crit Care Med. 2017.
38. Doherty LS, Kiely JL, Lawless G, McNicholas WT. Impact of nasal continuous positive airway pressure therapy on the quality of life of bed partners of patients with obstructive sleep apnea syndrome. Chest. 2003;124(6):2209-14.
39. Kiely JL, McNicholas WT. Bed partners' assessment of nasal continuous positive airway pressure therapy in obstructive sleep apnea. Chest. 1997;111(5):1261-5.

40. Berry RB, Uhles ML, Abaluck BK, Winslow DH, Schweitzer PK, Gaskins RA, et al. NightBalance Sleep Position Treatment Device Versus Auto-Adjusting Positive Airway Pressure for Treatment of Positional Obstructive Sleep Apnea. J Clin Sleep Med. 2019;15(7):947-56.
41. Levendowski DJ, Oksenberg A, Vicini C, Penzel T, Levi M, Westbrook PR. A systematic comparison of factors that could impact treatment recommendations for patients with Positional Obstructive Sleep Apnea (POSA). Sleep Med. 2018;50:145-51.
42. Al Oweidat K, Toubasi AA, Al-Iede M, Hasuneh MM, Al-Sayegh TN. Comparing the diagnostic value of the positional obstructive sleep apnea definitions. Respir Med. 2023;212:107227.
43. Zhu K, Bradley TD, Patel M, Alshaer H. Influence of head position on obstructive sleep apnea severity. Sleep Breath. 2017;21(4):821-8.

Figure 1: NightShift™ Sleep Positioner (Advanced Brain Monitoring, Carlsbad, USA) In the POSA trial, the device was worn on the back of the neck.

Figure 2: Consort diagram

Figure 3: The apnoea-hypopnoea index at baseline and after 3-months of Positional Therapy and Sham-Positional Therapy; Treatment difference = -4.414 events/hr (95% CI -7.768, -1.059), p= 0.011. Median change in AHI in Positional Therapy vs Sham-Positional Therapy was -6.60 events/hr (IQR -9.70, -3.90) vs -2.70 events/hr (IQR -7.60, 3.00).

Figure 1: NightShift™ Sleep Positioner (Advanced Brain Monitoring, Carlsbad, USA) In the POSA trial, the device was worn on the back of the neck. Original images provided with permission by JLK.

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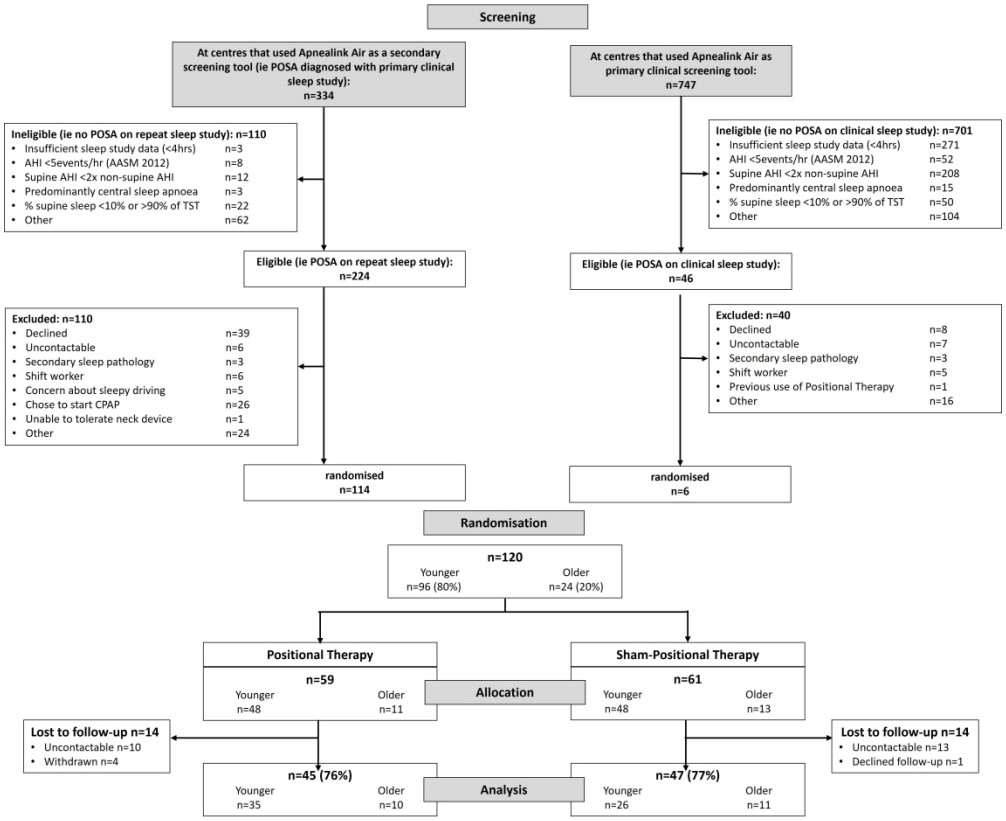

Figure 2: Consort diagram

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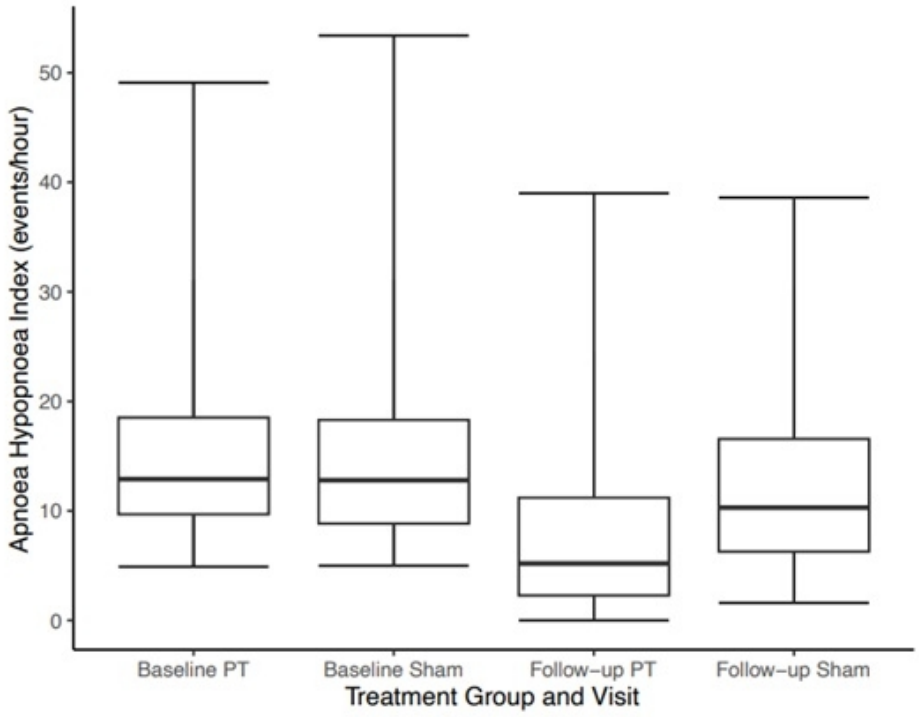


Figure 3: The apnoea-hypopnoea index at baseline and after 3-months of Positional Therapy and Sham-Positional Therapy; Treatment difference = -4.414 events/hr (95% CI -7.768, -1.059), p= 0.011. Median change in AHI in Positional Therapy vs Sham-Positional Therapy was -6.60 events/hr (IQR -9.70, -3.90) vs -2.70 events/hr (IQR -7.60, 3.00).

150x110mm (96 x 96 DPI)

SUPPLEMENTARY APPENDIX

Supplement to: Vibrotactile Positional Therapy for the treatment of positional obstructive sleep apnoea: a multicentre, randomised controlled trial

Julia L Kelly, Christopher D Turnbull, Roger Newson, Melissa Dobson, Emma L Hedley, Abdullah S ALQarni, Ann Nevinson, David Dawson, Annabel H Nickol, Sophie West, Nick P Talbot, Najib M Rahman, John R Stradling, Mary J Morrell on behalf of the POSA trial investigators*.

Table of Contents

1. POSA TRIAL INVESTIGATORS AND TRIAL STEERING COMMITTEE

Table s1: POSA trial investigators

Site:	Study Teams
A – Brompton Hospital, London	Prof Anita Simonds, Prof Michael Polkey, Dr Matthew Hind, Dr Alana Hare, Dr Julia Kelly, Dr Abdullah AlQarni
B – Freeman Hospital, Newcastle	Dr Sophie West, Joan Hughes, Abigail Nelson, Michael Scott
C – Churchill Hospital, Oxford	Dr Annabel Nickol, Dr Chris Turnbull, Bhumika Patel, Tara Harris, Jessica Trigg
E – Aintree Hospital, Liverpool	Dr Sonya Craig, Joanne Earley, Brogan Johnston
F – Harefield Hospital, London	Dr Shirmila Withana
G - Royal Free Hospital, London	Dr Swapna Mandal, Dr Anita Saigal, Dr Amar Shah
Oxford Respiratory Trials Unit	Dr Najib Rahman, Melissa Dobson, Emma Hedley, Mei Lau, Zoe Daskalopoulou, George Kitchen

Trial Steering Committee: Nicholas P Talbot (chair), Julia L Kelly, Christopher D Turnbull, Roger Newson, Emma L Hedley, Ann Nevinson (patient representative), Annabel H Nickol, Sophie West, John R Stradling, Mary J Morrell

2. METHODS

2.1. POSA: participating NHS Centres

Table s2: Participating NHS Centres and recruitment numbers

	Positional Therapy: N (%)	**Sham Positional Therapy: N (%)**	**Total: N (%)**
All participants Total	59 (100.0%)	61 (100.0%)	120 (100.0%)
Site: n(%)			
A – Brompton Hospital, London	7 (11.9%)	10 (16.4%)	17 (14.2%)
B – Freeman Hospital, Newcastle	23 (39.0%)	31 (50.8%)	54 (45.0%)
C – Churchill Hospital, Oxford	15 (25.4%)	15 (24.6%)	30 (25.0%)
E – Aintree Hospital, Liverpool	5 (8.5%)	1 (1.6%)	6 (5.0%)
F – Harefield Hospital, London	2 (3.4%)	3 (4.9%)	5 (4.2%)
G - Royal Free Hospital, London	7 (11.9%)	1 (1.6%)	8 (6.7%)

2.2. Home sleep test:

All home sleep tests were done by respiratory polygraphy (Apnealink Air, ResMed Ltd, Oxfordshire, UK), with measurements of airflow, respiratory effort, pulse oxygenation saturation and pulse rate. Test data were uploaded to a central server (AirView, ResMed Ltd) and analysed by an automated scoring algorithm using AASM 2012 scoring rules. The Apnealink Air contains user feedback which

shows if a successful night has been recorded. The device was re-used up to three nights, until > 4 hours of meaningful data was recorded.

2.3. Exclusion criteria:

An inability to give fully informed consent, unstable cardiac disease, cardiac arrhythmia corrected with an artificial pacemaker, use of supplemental oxygen, secondary sleep pathology (eg. Periodic Limb Movement Syndrome, Narcolepsy, Circadian Disorder, Obesity Hypoventilation Syndrome); or shift workers, concerns about sleepy driving or any other potentially dangerous symptom from physician, BMI of ≥40Kg/m^2, inability to sleep in a non-supine position, skin sensitivity or an open wound around neck, a neck circumference <12inches (30cm) or > 22inches (55cm), tics or tremors of the head, sleeping with head in upright position, a female of child-bearing potential that was pregnant or intended to become pregnant.

2.4. 3 month follow-up – Questions about patient experience and bed partner experience

Self-administered questionnaire:

- Did you complete the three-month trial of the Positional Therapy?
  - □ Yes
  - □ No. Please provide reasons: _____
- Did you feel the vibrational feedback?
  - □ No. □ Yes .
  - If yes, approximately how many times each night were you aware of the vibration? _____
- Overall, did the Positional Therapy help your symptoms?
  - □ Yes
  - □ No
- Will you continue to use the Positional Therapy?
  - □ Yes
  - □ No
  - □ Not sure

End of study researcher asked questions:

- DID THE PATIENT HAVE A BED PARTNER DURING THE STUDY?
  - No □
  - Yes □
  - If 'Yes', please complete questions below.
- PARTNER'S COMMENT ON CHANGES IN SNORING:
  - No change □
  - Improved □
  - Worse □
  - No comment □
- PARTNER'S COMMENT ON CHANGES IN PATIENT'S SLEEP QUALITY:
  - No change □
  - Improved □
  - Worse □
  - No comment □
- PARTNER'S COMMENT ON CHANGES IN OWN SLEEP QUALITY:

No change □
Improved □
Worse □
No comment □

- DOES THE PATIENT WISH TO KEEP THE DEVICE?
  Yes □
  No □

2.5. Post Covid Protocol ammendments:

During the first wave of COVID in March 2020, the trial was paused and the trial protocol, by necessity, was amended to provide remote options for all patient interactions i.e. consent, trial visits and diagnostic sleep studies (see Table s3 – Protocol v4.0).

After restarting recruitment in Nov 2020, using a new remote protocol, the central research team were responsible for the education of all trial patients in relation to the use of the Positional Therapy device. This occurred by telephone, with the aid of an online YouTube NightShift Instructional video (https://www.youtube.com/watch?v=A3Zc7LCrEiM). The postal service was used to deliver the study equipment and questionnaires.

Table s3: POSA trial Protocol Amendments

Version	Date issued	Author(s) of change	Details of changes made
V2.0	29/08/2019	Julia Kelly	The process of sending Airview data has been updated in the screening section to allow sites to send it in PDF format as well as uploads. Randomisation procedure updated to remove the need for an unblinded person to perform the randomisation procedure. TMG to review trial methodology and participant flow after completion of the first 10 participants
V3.0	13/12/2019	Julia Kelly	PSG subgroup: Addition of a RBHT subgroup in who detailed sleep study data will be collected on sleep quality and efficiency by home polysomnography
V4.0	26/06/2019	Julia Kelly	In line with the COVID-19 revised provision for clinical sleep services, the POSA trial protocol will now have the option to be delivered remotely in order to remove additional patient visits to the hospital sites. The protocol will vary between sites in accordance with local revision of clinical procedures and processes. All trial equipment will be cleaned in-line with local COVID-19 cleaning procedures.

			For transfer of home sleep study equipment and anonymised questionnaires, the patients will receive reply-paid, addressed envelopes.
V5.0	28/01/2021	Julia Kelly	Change of contact details for Trial Statistician as moving institutions. Amendment to the inclusion criteria from total % supine sleep >20, <90% of total sleep to total % supine sleep >10, <90% of total sleep. Amendment to Statement of Compliance in line with UK leaving the EU. Optional remote delivery of home sleep studies for the RBHT subgroup in line with COVID-19 care provision.
V6.0		Julia Kelly	TSC meeting decision to change the power of the study from 90% to 80%, thus reducing the sample size from 132 to 104. Change of ORTU email address for safety reporting Updated Sponsor name from Royal Brompton & Harefield NHS Foundation Trust to Royal Brompton and Harefield Hospitals, part of Guy's and St Thomas' NHS Foundation Trust (after merger on 1 February 2021).

3. RESULTS

3.1. Patient experience with Positional Therapy

Table s4: Subjective patient experience data after 3 months of Positional Therapy or Sham Positional Therapy in 91 out of 92 completing participants. N1 and N2 who completed each questionnaire in the Positional Therapy and Sham-Positional Therapy groups respectively.

	N1, N2	Positional Therapy: (n= 45 completers)	Sham Positional Therapy: (n= 47 completers)
Did you feel the vibrational feedback?: n(%)	45, 46		
No		2 (4.4%)	44 (72.1%)
Yes		43 (95.6%)	2 (3.3%)
Typical number of vibrations per night (if felt): median (IQR)	43	3.00 (2.00, 4.00)*	n/a
Overall, did the Positional Therapy help your symptoms?: n(%)	41, 45		
Yes		27 (65.9%)	10 (22.2%)
No		14 (34.1%)	35 (77.7%)
Will you continue to use the Positional Therapy?: n(%)	45, 44		
Yes		26 (57.8%)	15 (34.1%)
No		8 (17.8%)	7 (15.9%)
Not Sure		11 (24.4%)	22 (50.0%)

3.2. Age Group Comparisons 18-64 vs ≥65: Sham-Positional therapy treatment effects for outcomes measured at baseline and 3months.

Table s5: Age Group Comparisons 18-64 vs ≥65: Sham-Positional therapy treatment effects for sleep study outcomes measured at baseline and 3months. N1 and N2 with data for each sleep study parameter in the Positional Therapy and Sham-Positional Therapy groups respectively.

	18-64 years old					≥65 years old			
	N1, N2	**Effect**	**(95% CI)**	**P value**		**N1, N2**	**Effect**	**(95% CI)**	**P value**
AHI	35, 36	-4.6	(-8.5, -0.6)	.023		10, 11	-4.1	(-10.7, 2.5)	.21
Supine AHI	35, 36	-7.9	(-14.9, -0.9)	.027		10, 11	-11.0	(-18.8, -3.3)	.0081
Non-supine AHI	35, 36	1.2	(-1.8, 4.2)	.43		10, 11	3.0	(-1.1, 7.1)	.14
Events Index AI	35, 36	-1.3	(-3.2, 0.6)	.17		10, 11	-2.6	(-7.0, 1.8)	.23
Events Index HI	35, 36	-3.2	(-6.4, 0.0)	.052		10, 11	-1.3	(-5.8, 3.2)	.55
Oxygen desaturation ODI	35, 36	-5.1	(-10.2, -0.0)	.05		10, 11	-5.4	(-10.5, -0.4)	.037
Supine Percentage	35, 36	-13.6	(-24.0, -3.2)	.011		10, 11	-17.1	(-41.0, 6.8)	.15

Table s6: Age group comparisons 18-64 vs ≥65: Sham-Positional Therapy treatment effects for QoL outcomes measured at baseline and study end. N1 and N2 who completed each questionnaire in the Positional Therapy and Sham-Positional Therapy groups respectively.

	18-64 years old					≥65 years old			
	N1, N2	Effect	(95% CI)	P value		N1, N2	Effect	(95% CI)	P value
Quality of Life: higher scores means better status									
SF-36									
Physical functioning	35, 32	-2.3	(-9.7, 5.2)	.55		10, 12	-2.7	(-19.5, 14.0)	.74
Role limitations due to physical health	34, 31	6.9	(-7.7, 21.4)	.35		10, 12	-8.6	(-41.2, 24.0)	.59
Role limitations due to emotional problems	34, 31	9.6	(-5.6, 24.7)	.21		10, 12	-9.2	(-35.5, 17.0)	.47
Energy/fatigue	31, 28	2.5	(-4.8, 9.7)	.5		10, 12	3.1	(-15.0, 21.2)	.72
Emotional well-being	34, 31	6.0	(-2.0, 14.0)	.14		10, 12	10.2	(1.9, 18.4)	.018
Social functioning	31, 31	6.5	(-3.6, 16.6)	.2		10, 12	11.1	(-9.4, 31.6)	.27
Pain	34, 31	0.3	(-7.2, 7.7)	.94		10, 12	7.3	(-13.0, 27.7)	.46
General health	34, 30	1.5	(-6.0, 9.0)	.69		10, 11	-3.9	(-15.2, 7.5)	.48
FOSQ	33, 34	0.6	(-0.5, 1.7)	.31		10, 12	0.7	(-0.4, 1.7)	.21
FOSQ general productivity subscale	33, 34	0.1	(-0.1, 0.3)	.36		10, 12	0.2	(-0.1, 0.5)	.23
FOSQ social outcome subscale	32, 34	0.2	(-0.1, 0.5)	.21		10, 12	0.2	(-0.2, 0.5)	.3
FOSQ activity level subscale	33, 34	0.2	(-0.0, 0.5)	.073		10, 12	0.0	(-0.3, 0.3)	.97
FOSQ vigilance subscale	33, 34	0.1	(-0.1, 0.4)	.33		10, 12	0.0	(-0.2, 0.3)	.76
FOSQ intimate activity subscale	27, 31	-0.0	(-0.3, 0.3)	.94		6, 7	0.1	(-0.5, 0.6)	.85
EQ-5D-5L - Your health today	35, 32	-2.4	(-8.8, 4.0)	.46		10, 12	-3.4	(-14.5, 7.7)	.52
EQ-5D-5L TTO score	35, 31	0.0	(-0.1, 0.1)	.66		10, 12	0.0	(-0.1, 0.2)	.83
Quality of Life: lower scores means better status									
Epworth sleepiness scale	33, 32	-0.5	(-1.9, 0.9)	.47		7, 12	-0.9	(-2.9, 1.2)	.38
HADS anxiety score	47, 48	-0.6	(-2.3, 1.1)	.47		12, 13	-0.5	(-4.4, 3.4)	.78
HADS depression score	47, 48	-0.8	(-2.1, 0.6)	.26		12, 13	0.3	(-2.4, 2.9)	.84
TDI	32, 29	0.6	(-1.9, 3.1)	.64		9, 9	-0.1	(-1.4, 1.2)	.89
PSQI global score	26, 27	-1.2	(-2.4, 0.0)	.058		9, 8	-0.6	(-2.8, 1.5)	.54

3.3. Bed partners' experience with Positional Therapy

Table s7: Bed partners' experience data after 3 months of Positional Therapy or Sham-Positional Therapy in 89 out of 92 completing participants. N1 and N2 who completed each questionnaire in the Positional Therapy and Sham-Positional Therapy groups respectively.

	N1,N2	Positional Therapy: (n=45 completers)	Sham-Positional Therapy: (n=47 completers)
Did the participant have a bed partner during the study?: n(%)	45,44		
Yes		32 (71.1%)	34 (77.3%)
No		13 (28.9%)	10 (22.7%)
Partner's comment on changes in snoring: n(%)	32,34		
No change		8 (25.0%)	22 (64.7%)
Improved		20 (62.5%)	8 (23.5%)
Worse		1 (3.1%)	2 (5.9%)
No comment		3 (9.3%)	2 (5.9%)
Partner's comment on changes in patient's sleep quality: n(%)	32,34		
No change		7 (21.9%)	21 (61.8%)
Improved		21 (65.6%)	3 (8.8%)
Worse		0 (0.0%)	4 (11.8%)
No comment		4 (12.5%)	6 (17.6%)
Partner's comment on changes in own sleep quality: n(%)	32,34		
No change		11 (34.4%)	22 (64.7%)
Improved		16 (50.0%)	3 (8.8%)
Worse		1 (3.1%)	3 (8.8%)
No comment		4 (12.5%)	6 (17.6%)

3.4. Positional Therapy adherence and side effects data

Table s8: NightShift adherence data after 3 months of Positional Therapy or Sham-Positional Therapy in 73 out of 92 completing participants

	Positional Therapy (n= 38 out of 45 completers (84%))	Sham-Positional Therapy (n= 35 out of 47 completers (74%))
Average nights used in 90-day period (nights)		
Median (IQR)	66 (49, 85)	68 (23, 85)
Range	(0, 90)	(0, 89)
Average nightly use per night used (hrs:mins):		
Median (IQR)	6:55 (5:50, 7:45)	7:25 (6:34, 7:55)
Range	(0:00, 9:56)	(0:00, 13:15)
Average nightly use over 90 days (hrs:mins):		
Median (IQR)	5:00 (2:49, 6:13)	5:26 (2:00, 6:25)
Range	(0:00, 8:41)	(0:00, 7:53)

Table s9: Side effects reported after 3 months of Positional Therapy or Sham-Positional Therapy in 73 out of 92 completing participants

Side effect	**Positional Therapy (83 comments** from n=39 of 45 completers; 87%**)**	**Sham**- Positional Therapy **(75 comments** from n= 36 of 47 completers (77%)**)**
Waking due to vibrational feedback	21	0
Strap/device discomfort	19	23
Position discomfort; including hips, shoulders, arms, neck	13	4
Snoring continued	7	10
Device falling off	5	2
Battery life/ charging issues	4	2
Difficulty falling asleep	3	1
Noise from vibrations	3	0
Device switched off during the night	3	2
Strap tension issues	2	7
Frequent awakenings	2	4
Remembering to wear device	1	1
Symptoms continued	0	10
No vibration and therefore no benefit	0	5
Device fitting	0	1
Looked silly	0	1
Dry throat	0	1
Hyper aware of supine sleep	0	1

3.5. Responders to Positional Therapy compared with non-responders

Table s10: Comparison of Responders (AHI reduced by ≥5events/hr) and Non-responders in the Positional Therapy Group (n= 45). N1 and N2 with data for each characteristic in the Positional Therapy and Sham-Positional Therapy groups respectively.

	N1, N2	***Non-responders: (n= 14)(100%)***	***Responders: (n= 31)(100%)***	***Total: (n=45)(100%)***
Site:	14, 31			
A - Brompton		4 (28.6%)	2 (6.5%)	6 (13.3%)
B - Newcastle		4 (28.6%)	15 (48.4%)	19 (42.2%)
C - Oxford		5 (35.7%)	8 (25.8%)	13 (28.9%)
F - Harefield		0 (0.0%)	1 (3.2%)	1 (2.2%)
G - Royal Free		1 (7.1%)	5 (16.1%)	6 (13.3%)
Randomisation age group:	14, 31			
18-64		10 (71.4%)	25 (80.6%)	35 (77.8%)
65+		4 (28.6%)	6 (19.4%)	10 (22.2%)
Randomisation OSA severity:	14, 31			
<20		11 (78.6%)	23 (74.2%)	34 (75.6%)
20+		3 (21.4%)	8 (25.8%)	11 (24.4%)
Age at randomisation (years):	14, 31	55.79 (13.30)	54.39 (10.68)	54.82 (11.42)

Smoking (pack years):	5,13	10.20 (7.85)	15.19 (11.99)	13.81 (11.01)
BMI (kg/m²):	14, 31	28.36 (4.99)	28.34 (4.52)	28.35 (4.61)
Neck circumference(cm):	14, 31	40.19 (3.70)	39.56 (3.77)	39.76 (3.72)
Gender:	14, 31			
Male		9 (64.3%)	21 (67.7%)	30 (66.7%)
Female		5 (35.7%)	10 (32.3%)	15 (33.3%)
Race/Ethnicity:	14, 31			
White		13 (92.9%)	29 (93.5%)	42 (93.3%)
Hispanic/Latino		0 (0.0%)	1 (3.2%)	1 (2.2%)
Asian		1 (7.1%)	1 (3.2%)	2 (4.4%)
Smoking Status:	14, 31			
Never smoked		9 (64.3%)	16 (51.6%)	25 (55.6%)
Ex-smoker		3 (21.4%)	14 (45.2%)	17 (37.8%)
Current smoker		2 (14.3%)	1 (3.2%)	3 (6.7%)
Reason for referral:	14, 31			
Snoring		0 (0.0%)	10 (32.3%)	10 (22.2%)
Excessive Daytime sleepiness		0 (0.0%)	1 (3.2%)	1 (2.2%)
Fatigue		1 (7.1%)	1 (3.2%)	2 (4.4%)
Unrefreshing Sleep		3 (21.4%)	4 (12.9%)	7 (15.6%)
Screening (pre-op or due to co-morbidity e.g. resistant HT)		2 (14.3%)	2 (6.5%)	4 (8.9%)
Other		2 (14.3%)	4 (12.9%)	6 (13.3%)
Witnessed apnoea		6 (42.9%)	9 (29.0%)	15 (33.3%)
Who was the main driver for the referral?:	14, 31			
Patient		7 (50.0%)	9 (29.0%)	16 (35.6%)
Bed-partner		4 (28.6%)	11 (35.5%)	15 (33.3%)
GP		0 (0.0%)	4 (12.9%)	4 (8.9%)
Other medical specialist		3 (21.4%)	7 (22.6%)	10 (22.2%)
Medical History:	14, 31			
Coronary Artery Disease		0 (0.0%)	3 (9.7%)	3 (6.7%)
Hypertension		4 (28.6%)	5 (16.1%)	9 (20.0%)
Diabetes		1 (7.1%)	2 (6.5%)	3 (6.7%)
Anxiety		4 (28.6%)	12 (38.8%)	16 (35.6%)
Depression		3 (21.4%)	12 (67.8%)	15 (.3%)
Insomnia		2 (14.3%)	6 (19.4%)	8 (17.7%)
Rhinitis/Other Nasal Problem		4 (28.6%)	11 (35.5%)	15 (33.3%)
Stroke or TIA		0 (0.0%)	2 (6.5%)	2 (4.4%)
GP visits in past month (n):	14, 31	0.1 (0.4)	0.3 (0.5)	0.2 (0.5)
Days off work in past month (n):	13, 25	0.0 (0.0)	0.1 (0.6)	0.1 (0.5)
In past month has the patient had any incidents causing injury:		0 (0.0%)	0 (0.0%)	0 (0.0%)
In past month has the patient had a Road Traffic Accident (n%):		0 (0.0%)	0 (0.0%)	0 (0.0%)
Baseline Sleep Study:				
AHI (e/hr)	14, 31	9.2 (6.4, 17.5)	13.0 (10.5, 21.8)	12.9 (9.7, 18.5)
Supine AHI (e/hr):	14, 31	21.2 (9.4, 30.1)	26.4 (17.6, 32.8)	24.7 (17.3, 32.1)
Non-supine AHI (e/hr)	14, 31	3.2 (0.7, 9.6)	4.8 (2.7, 7.0)	4.7 (2.4, 7.0)
AI (e/hr)	14, 31	1.9 (1.2, 5.5)	3.6 (1.3, 6.8)	3.6 (1.3, 6.7)

HI (e/hr)	14, 31	6.1 (4.7, 9.6)	10.2 (8.1, 12.1)	9.3 (6.8, 11.9)
ODI (e/hr)	14, 31	11.0 (7.1, 20.9)	16.3 (11.7, 22.7)	15.8 (10.7, 20.9)
Supine Percentage	14, 31	32.6 (22.5, 79.8)	50.0 (36.0, 62.0)	50.0 (33.0, 65.8)
Baseline QoL:				
ESS	12, 29	9.5 (5.8)	8.9 (3.8)	9.10 (4.4)
FOSQ total scale	14, 31	16.7 (3.6)	16.9 (3.0)	16.9 (3.2)
FOSQ general productivity	14, 31	3.5 (0.6)	3.5 (0.6)	3.5 (0.6)
FOSQ social outcome	14, 30	3.5 (0.8)	3.7 (0.6)	3.63 (0.7)
FOSQ activity level	14, 31	3.2 (0.8)	3.1 (0.7)	3.15 (0.7)
FOSQ vigilance	14, 31	3.3 (0.9)	3.4 (0.6)	3.4 (0.7)
FOSQ intimate activity	10, 27	3.1 (0.9)	3.2 1.0)	3.2 (0.9)
HADS anxiety score	14, 31	7.1 (5.5)	7.1 (5.0)	7.1 (5.1)
HADS depression score	14, 31	5.6 (4.0)	6.0 (5.3)	5.8 (4.9)
TDI	14, 30	3.6 (5.8)	2.1 (3.4)	2.6 (4.3)
SF-36 Physical functioning	14, 31	76.8 (33.3)	76.9 (24.1)	76.9 (27.0)
SF-36 Role limitations due to physical health	14, 31	62.5 (38.9)	64.2 (36.4)	63.6 (36.8)
SF-36 Role limitations due to emotional problems	14, 30	73.8 (37.4)	70.0 (41.4)	71.2 (39.8)
SF-36 Energy/fatigue	13,29	45.4 (21.8)	44.8 (24.3)	45.0 (23.3)
SF-36 Emotional well-being	14, 31	72.6 (15.8)	65.2 (24.8)	67.5 (22.5)
SF-36 Social functioning	13, 29	71.2 (29.5)	69.0 (30.6)	69.6 (29.9)
SF-36 Pain	14, 31	66.1 (25.2)	65.2 (24.5)	65.5 (24.5)
SF-36 General health	14, 31	50.4 (22.1)	51.5 (21.6)	51.1 (21.5)
EQ-5D-5L - Your health today(baseline):	14, 31	67.5 (17.0)	73.9 (19.0)	71.9 (18.4)
EQ-5D-5L TTO score	14, 31	0.8 (0.2)	0.8 (0.2)	0.8 (0.2)
PSQI global score	13, 27	8.5 (3.7)	8.6 (4.9)	8.6 (4.5)

3.6. Post hoc sensitivity analysis

We conducted a *post hoc* sensitivity analysis, using inverse completeness-propensity weighting, also known as inverse-probability weighting (Seaman and White, 2011). In summary, the main analyses of outcomes measured at baseline and at study end were re-done with completeness-propensity weights, which weight up complete participants with low probability of completeness and weight down complete participants with high probability of completeness. This makes the AHI-complete participants appear more similar to the full set of participants originally randomised.

We chose a list of baseline covariates to be used as completeness predictors in a logistic completeness-propensity model to derive inverse completeness-propensity weights. These predictors were: female gender indicator; smoking status indicators (ex-smoker, current smoker, and missing, compared to a baseline of lifelong nonsmoker); Group 2 indicator (sham); age at randomisation (years); missing randomisation-age indicator; number of GP visits in month before randomisation; sick days taken off work in month before randomisation; missing sick-days indicator. We used these covariates to fit a logistic regression model predicting AHI completeness from these covariates, and defined the completeness-propensity score as the fitted probability of completeness from that model, and defined the inverse completeness-propensity weight as the reciprocal of that fitted probability for AHI-complete subjects.

This method produced completeness-propensity scores in the AHI-complete subjects ranging from 0.506 to 1.000, and therefore inverse completeness-propensity weights ranging from 1.000 to 1.976.

Balance checks on the completeness-propensity weights were done using the SSC packages somersd (Newson, 2006) and scsomersd to compute values for a scenario-comparison Somers' *D* index comparing the AHI-complete subjects with the full set of randomised subjects.

For each predictor, we computed Somers' *D* in two versions, the first assuming that the random AHI-complete subject was chosen with equal probability for all subjects ("Unweighted") and the second assuming that the random AHI-complete subject was chosen with a probability proportional to its inverse completeness-propensity weight ("Propensity-weighted"), while the random subject from the full set of randomized subjects was chosen with equal probability for all randomised subjects for both versions of Somers' *D*. Baseline covariates of age, pre-randomisation GP visits, and pre-randomisation days off work predicted AHI-completeness. The Somers' *D* estimates (unweighted and propensity-weighted) are tabulated in **Table s11** and plotted in **Figure s10**.

We used the AHI-completeness propensity weights in a new version of the analyses comparing the trial arms (adjusted for age group and baseline AHI), this time using the propensity weights and calculating confidence intervals using weighted Huber variances. The post-hoc completedness-propensity weighted analysis for the primary estimand provided similar results to our main analysis, with a treatment difference in the AHI of 4.1 events/ hr (95%CI 0.7, 7.6, p=0.02).

Full details of the methods were presented at the 2024 London Stata Conference, 12-13 September, London, UK under the following reference:

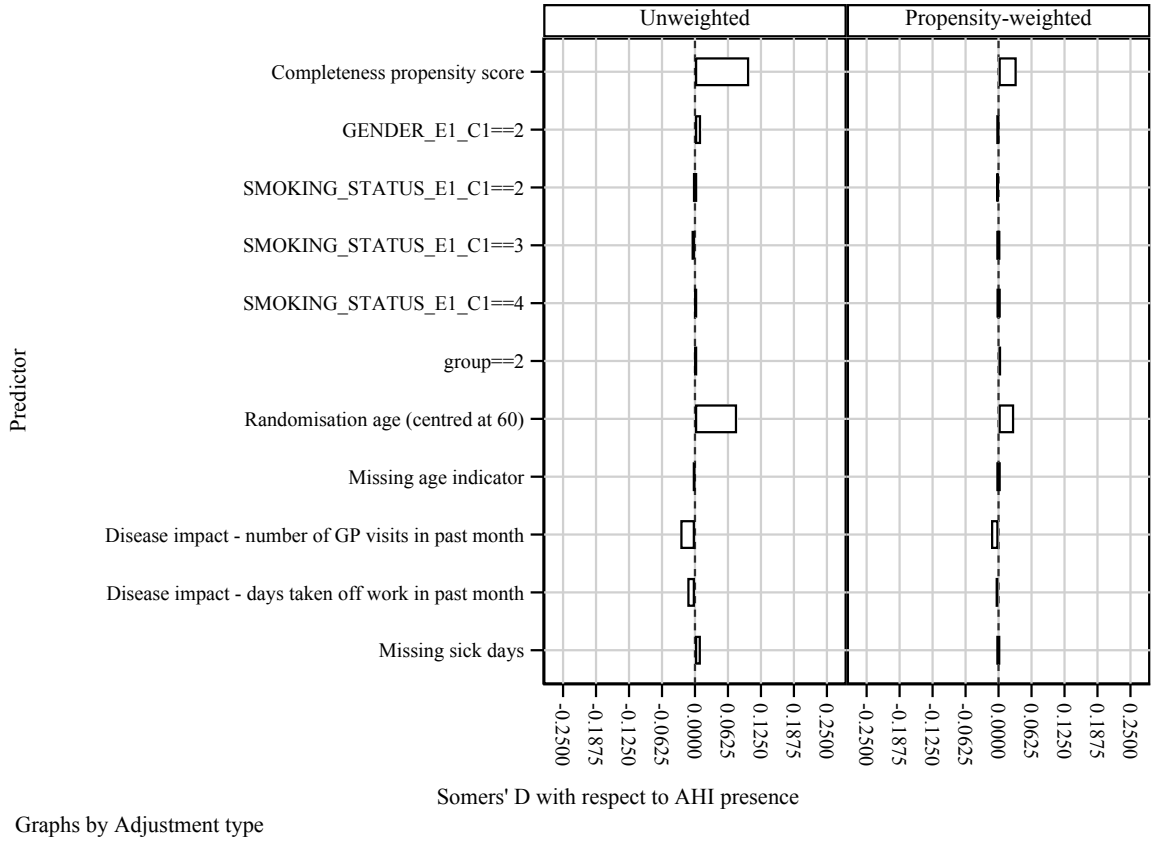
Newson RB. Balance and variance inflation checks for completeness-propensity weights.

https://www.stata.com/meeting/uk24/slides/UK24_Newson.pdf

Table s11. Somers' D estimates (unadjusted and propensity-adjusted) for predictive covariates in the propensity model for AHI completeness

Predictor	*Unweighted Somers' D*	*Propensity-weighted Somers' D*
Completeness propensity score	0.103	0.035
GENDER_E1_C1==2	0.012	-0.003
SMOKING_STATUS_E1_C1==2 (ex-smoker)	0.000	-0.004
SMOKING_STATUS_E1_C1==3 (current smoker)	-0.007	-0.001
SMOKING_STATUS_E1_C1==4 (missing)	0.003	0.000
group==2 (Sham)	0.003	0.005
Randomisation age (centred at 60)	0.080	0.030
Missing age indicator	-0.003	0.000
Disease impact - number of GP visits in past month	-0.028	-0.014
Disease impact - days taken off work in past month	-0.015	-0.006
Missing sick days	0.011	-0.001

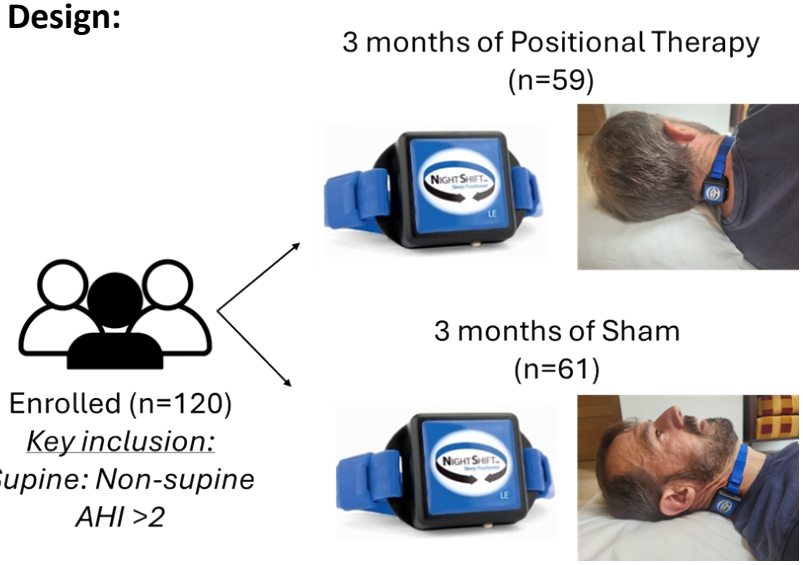
Figure s1. Somers' D estimates (unadjusted and propensity-adjusted) for predictive covariates in the propensity model for AHI completeness



Vibrotactile positional therapy for the treatment of positional obstructive sleep apnoea: a multicentre, randomised controlled trial

Kelly J *et al. Thorax* 2025. DOI: 10.1136/thorax-2024-222681

Study Design:



Results of Trial of Positional Therapy vs. Sham (3 months):

- Significantly improved Apnoea Hypopnoea Index (AHI; 4.41 events/hour)
- Improved sleep quality
- Improved bed partner sleep quality
- Did not improve sleepiness (Epworth Sleepiness Scale)
- Did not improve quality of life