The impact of technology in the myofunctional therapy treatment of Obstructive Sleep Apnea Syndrome.

2023 Biomedical Research Awards (BRA)

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FollowUp Form

Award Information

In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:

- *Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication? (We do publish the Final Report on our website, so this does need to be complete and polished.)*
- *Does this Final Report provide the level of detail, etc. that you would expect, if you were the reviewer?*

Title of Project:*

The impact of technology in the myofunctional therapy treatment of Obstructive Sleep Apnea Syndrome.

Award Type

Biomedical Research Award (BRA)

Period of AAOF Support

July 1, 2023 through June 30, 2024

Institution

Case Western Reserve University

Names of principal advisor(s) / mentor(s), co-investigator(s) and consultant(s)

Juan Martin Palomo (PI), Ambrose Chiang (CI), Denise Dewald (CI), Luciane Macedo de Menezes (CI)

Amount of Funding

$39,999.75

Abstract

(add specific directions for each type here)

Obstructive sleep apnea (OSA) is an important public health problem that affects a significant part of the population. OSA is characterized by recurrent partial or total obstruction of the upper airway (UA) during sleep, negatively affecting people's quality of life in the short and long term. The orthodontists' field of expertise is closely related to the UA, placing them in a strategic position to assess air passage failures and proceed accordingly. Myofunctional exercise training is a therapeutic option with shown efficacy for treating sleep-disordered breathing. The main problem with this therapy is the lack of compliance, which is only around 10%. The use of smartphone applications may improve adherence to exercises and training, and help form a habit that potentially could be life-changing.
The objective of this study is to compare the effects of myofunctional exercises when using an app versus using traditional analog methods in adult subjects diagnosed with OSA. A total of 60 subjects, 30 in the app group, and 30 in the analog group will be enrolled following proper inclusion and exclusion criteria. The groups will be matched by age, sex, BMI, and AHI (OSA severity). The baseline protocol will include: age, sex, neck size, body mass index (BMI), tongue and lip strength using the Iowa Oral Performance Instrument (IOPI), neck muscle tone using a surface EMG, Pittsburgh Sleep Quality Index, STOP-Bang questionnaire, NOSE questionnaire, the Insomnia Severity Index, the Epworth Sleepiness Scale, airway collapsibility using an Ultra-sound exam (AmCad), sleep stages analysis, oxygen saturation, and heart rate variation collected with the Belun ring, as well as snoring presence, intensity, and length using Snore app. Subjects will be instructed to perform myofunctional exercises under the guidance of the Airway Gym app or the same exercises printed out in a form. An initial session will be scheduled to collect baseline data, train subjects in the use of the app, and learn the exercises. The average myofunctional therapy is 20 minutes per day, five days a week. Subjects will be followed monthly, collecting progress data, and final data will be collected at the end of 3 months. Compliance will also be evaluated, and subjects will be categorized as adherent or non-adherent. In the app group, adherent subjects will be the ones for whom the app registers an appropriate use of more than 15 minutes per day for at least 80% of the study period. All other subjects will be considered non-adherent. For the analog group, a calendar sheet will be used, filled by the subject, and the same criteria will be applied. After three months of exercises, a re-evaluation will be performed by repeating the baseline exams on both groups, and the results will be compared.

Respond to the following questions:

Detailed results and inferences:*

If the work has been published, please attach a pdf of manuscript below by clicking "Upload a file".
OR
Use the text box below to describe in detail the results of your study. The intent is to share the knowledge you have generated with the AAOF and orthodontic community specifically and other who may benefit from your study. Table, Figures, Statistical Analysis, and interpretation of results should also be attached by clicking "Upload a file".

Palomo AAOF BRA Data 2026 Final.pdf
This randomized controlled trial evaluates the efficacy and adherence rates of myofunctional exercises delivered via a smartphone application compared to a self-directed manual method in individuals with obstructive sleep apnea (OSA). The outcomes of this study may improve understanding of how digital technologies might boost accessibility, adherence, and treatment efficacy for patients seeking noninvasive alternatives to conventional OSA care.

Study Design
This research was a prospective, randomized, controlled clinical trial conducted in the Orthodontics department at Case Western Reserve University School of Dental Medicine. The study was unsponsored and received approval from the Institutional Review Board (IRB study20231615). All participants provided informed consent prior to involvement.
Data was compiled and consolidated via Microsoft Excel. The recorded data included Snore Score, Snore Duration, AHI4, mean SpO2, minimum SpO2, Mean Pulse Rate, Sleep Efficiency, IOPI anterior, IOPI posterior, IOPI right, IOPI left, STOP BANG, NOSE, Epworth Sleepiness Scale, PROMIS Sleep Disturbance, and compliance.
Patients
A total of 40 participants were recruited and randomized into two study arms: 16 patients were assigned to the analog exercise group and 24 patients to the app-based myofunctional therapy group. Voluntary withdrawal or loss to follow-up occurred in both groups over the course of the study. 11 patients in the analog group and 14 patients in the app group completed all study requirements and were included in the final analysis.
Muscle Strength (IOPI)
Within-group analysis demonstrated statistically significant enhancements in anterior tongue strength ($p = 0.0128$), posterior tongue strength ($p = 0.00075$), and left buccinator strength ($p = 0.0155$) from baseline to the final assessment. The strength of the right buccinator exhibited no statistically significant difference ($p = 0.106$). Comparisons across groups revealed no statistically significant differences in any of the IOPI measures, suggesting that both administration strategies (app-based and analog) were equally successful in enhancing oral muscular strength over time.
Sleep Metrics (Belun Ring Data)
Apnea–Hypopnea Index (AHI) – All Participants
Across all participants (n = 23), both groups demonstrated a reduction in AHI from baseline to final measurement. The analog group decreased from 11.47 ± 7.16 to 9.39 ± 8.32 events/hour (Δ = –2.08), and the app group decreased from 10.06 ± 9.67 to 7.80 ± 6.77 events/hour (Δ = –2.26).
Although both groups showed improvement, the intra-group reductions were not statistically significant (analog $p = 0.2078$; app $p = 0.1591$).
The overall group comparison approached significance ($p = 0.0510$), but did not meet the threshold for statistical significance.
AHI in Participants With Baseline AHI > 5
A subset analysis (n = 15) was performed on participants with an initial AHI greater than 5. The analog group reduced from 15.03 ± 5.19 to 11.52 ± 9.21 events/hour (Δ = –3.52; $p = 0.1121$), which did not reach significance. The app group showed a larger reduction, decreasing from 14.25 ± 10.33 to 9.51 ± 7.76 events/hour (Δ = –4.74), achieving statistical significance ($p = 0.0353$). Across all participants with baseline AHI > 5, AHI decreased significantly (Δ = –4.17; $p = 0.0056$). This indicates that clinically meaningful improvements were primarily concentrated among individuals beginning with elevated disease severity.
Minimum Oxygen Saturation (SpO_2 Minimum)
Minimum oxygen saturation remained stable across groups. The analog group decreased slightly from 80.76 ± 6.08 to 80.26 ± 4.67 (Δ = –0.50; $p = 0.6707$). The app group increased modestly from 80.20 ± 6.09 to 81.00 ± 6.46 (Δ = +0.80; $p = 0.6961$). No significant differences were detected either within or between groups (overall $p = 0.8381$).
Mean Oxygen Saturation (SpO_2 Mean)
The analog group exhibited a statistically significant decline in mean oxygen saturation, decreasing from 93.88 ± 1.94 to 92.78 ± 1.78 (Δ = –1.10; $p = 0.0067$). The app group maintained stable oxygenation (93.62 ± 2.83 to 93.98 ± 2.25; Δ = +0.35; $p = 0.6498$). Between-group comparison at completion did not reach significance (overall $p = 0.6674$). While changes were small in magnitude, the analog group showed a measurable reduction in mean saturation.
ODI 3% (Oxygen Desaturation Index)
The analog group demonstrated a slight increase in ODI 3% (Δ: +1.16 events/hour), whereas the app group showed a reduction (Δ: −6.63 events/hour) of 35.5% by going from 18.7 to 12.07.
The between-group comparison demonstrated a trend towards statistical significance ($p = 0.0556$).
Pulse Rate

Mean pulse rate remained consistent over time in both groups. The analog group changed from 64.31 ± 5.81 to 64.16 ± 5.03 ($\Delta = -0.15$; $p = 0.8964$), and the app group from 67.70 ± 7.99 to 66.85 ± 6.31 ($\Delta = -0.85$; $p = 0.5274$). No significant differences were observed between groups (overall $p = 0.5392$). Pulse rate variability appeared minimal, suggesting stable autonomic activation during sleep.

Sleep Efficiency

Sleep efficiency was initially higher in the app group (87.45 ± 8.69) compared with the analog group (78.21 ± 12.61). Both groups maintained their sleep efficiency levels throughout the study. The analog group showed a small increase from 78.21 ± 12.61 to 81.43 ± 11.64 ($\Delta = +3.22$; $p = 0.4137$), while the app group showed a negligible change (87.45 ± 8.69 to 87.64 ± 8.67; $\Delta = +0.20$; $p = 0.9499$). No significant within-group or between-group changes were identified (overall $p = 0.5413$).

Results of the Questionnaire

Epworth Sleepiness Scale (ESS)

Both groups demonstrated reductions in daytime sleepiness following the 3-month intervention. The analog group showed a significant decrease in ESS scores, improving from 10.09 ± 5.20 at baseline to 7.27 ± 5.18 at final assessment ($\Delta = -2.82$; $p = 0.0096$). The app group also showed a reduction (9.43 ± 4.52 to 8.36 ± 3.82; $\Delta = -1.07$), although this change did not reach statistical significance ($p = 0.1969$). Across all participants, ESS scores decreased significantly ($\Delta = -1.84$; $p = 0.0054$), indicating an overall improvement in daytime sleepiness associated with daily myofunctional exercises.

PROMIS Sleep Disturbance

Sleep disturbance scores mirrored the pattern observed in ESS outcomes. The analog group demonstrated a significant reduction from 10.09 ± 5.20 at baseline to 7.27 ± 5.18 post-intervention ($\Delta = -2.82$; $p = 0.0096$). The app group showed a modest improvement (9.43 ± 4.52 to 8.36 ± 3.82; $\Delta = -1.07$), which did not reach statistical significance ($p = 0.1969$). When analyzed collectively, participants experienced a significant overall improvement in sleep disturbance ($\Delta = -1.84$; $p = 0.0054$). These findings suggest that both delivery methods result in measurable improvements in perceived sleep quality, with stronger effects observed in the analog group.

SnoreLab

An analysis within the group showed that snoring-related factors got a lot better. Both snore score ($p = 0.0448$) and snore duration ($p = 0.0081$) showed substantial reductions from baseline to end measures. The differences between groups for these measures were not statistically significant, indicating similar decreases in snoring in both intervention groups.

Compliance

Compliance rates, assessed through analog exercise logs and app-tracked performance data, were significantly higher in the analog group compared with the smartphone application group (64.4% vs 42.9%, $p = 0.0121$); however, both cohorts demonstrated satisfactory adherence, indicating that digital delivery did not hinder engagement over the 3-month intervention. The higher adherence observed in the analog group may partially account for their greater improvement in minimum oxygen saturation, underscoring the role of consistent practice in achieving physiological gains. Despite this difference, both delivery methods successfully supported regular participation, reinforcing that myofunctional therapy can be feasibly administered through either traditional paper-based guidance or a smartphone app, with both formats contributing to improved muscle strength, reduced daytime sleepiness, enhanced subjective sleep quality, and decreased snoring metrics.

Conclusion

Both analog and app-based myofunctional therapy produced measurable improvements in upper-airway muscle tone and sleep-related outcomes. Posterior tongue strength, assessed through the Iowa Oral Performance Instrument, showed significant within-group gains, supporting the effectiveness of structured orofacial exercise across delivery formats. When both groups were analyzed together, reductions in AHI, snore duration, Epworth Sleepiness Scale scores, and PROMIS Sleep Disturbance scores reached statistical significance, indicating broad improvements in both physiological and subjective sleep parameters.

The analog group demonstrated higher overall compliance, which may have contributed to the magnitude of improvement observed in this cohort. The Belun Ring provided reliable, noninvasive physiologic data that supported the observed treatment effects and demonstrated the utility of home-based digital monitoring in assessing airway therapy outcomes. These findings align with prior literature showing that strengthening orofacial musculature can meaningfully enhance airway stability and reduce sleep-disordered breathing events.

Overall, the results of this study support myofunctional therapy as a feasible, accessible, and clinically valuable adjunctive treatment for individuals with mild to moderate obstructive sleep apnea. Both traditional and smartphone-based delivery methods offer practical pathways for implementing daily exercises, making MFT a flexible option for diverse patient populations.

Were the original, specific aims of the proposal realized?*

Yes, all specific aims were successfully realized.
This randomized controlled study evaluated the efficacy of myofunctional therapy (MFT) delivered via a smartphone application versus a conventional analog method, expanding on previous pilot work by incorporating both Belun Ring physiological data and SnoreLab acoustic analysis. Our baseline and post-treatment IOPI values (46 → 51 kPa) fell within the expected range reported in the literature for mild-to-moderate hypotonicity (35–60 kPa; Navarro 2025, Rodríguez-Alcalá 2022, Li 2025) and were comparable to those seen in other OSA cohorts before and after MFT intervention. Because untreated OSA patients typically exhibit tongue pressures lower than healthy adults (~30–60 kPa vs 65–70 kPa; Clark 2012; Adams 2013), the post-intervention values in our cohort (~51 kPa) approximate levels described in compensated or non-hypotonic phenotypes. The magnitude of improvement (~4–5 kPa) is consistent with gains reported in other clinical trials (Rodríguez-Alcalá 2022; Li 2025; Navarro 2025), supporting the reproducibility of oropharyngeal strengthening across studies. Although not all individual IOPI outcomes reached statistical significance, the direction of change was uniform, reaffirming existing evidence that MFT reliably increases tongue and orofacial muscle strength. These increases likely reflect enhanced activation of the genioglossus and related airway dilator muscles, contributing to improved airway tone. Even modest increases in peak pressure (≈5 kPa) have been associated with meaningful improvements in airway stability and AHI reduction in prior literature, which aligns with patterns seen in our results.
The Belun Ring provided detailed physiologic insight into how MFT influences sleep-related respiratory parameters. Consistent with O'Connor-Reina et al. (2024), Li et al. (2025), Rodríguez-Alcalá et al. (2022), and Guimarães et al. (2009), our findings demonstrated a downward trend in AHI for both groups, confirming that MFT can reduce the frequency of airway obstruction events even when differences do not reach statistical significance. SpO_2 mean and minimum values remained stable across groups, a pattern also noted by Li et al. (2025), who observed improvements in breathing events without marked desaturation changes. Pulse rate remained unchanged, indicating no increase in sympathetic drive or sleep fragmentation, and sleep efficiency showed stability similar to findings by Bui-Diem et al. (2023) and Goswami et al. (2019), where patients reported better perceived sleep quality despite unchanged objective efficiency. Together, these results suggest that MFT improves respiratory stability during sleep not necessarily by altering total sleep time but by reducing arousals and improving upper-airway control.
The findings of the present study are consistent with those reported by O'Connor-Reina et al.(2020), in which the use of a myofunctional therapy application resulted in a substantial reduction in oxygen desaturation events. Specifically, the authors reported a 46.5% decrease in ODI, from 36.31 to 19.4 events/hour.
SnoreLab findings provided additional objective evidence of improvement. Our study demonstrated an average decrease in snore duration of 12 minutes, consistent with O'Connor-Reina et al. (2024), who reported 16 minutes, and Rodríguez-Alcalá et al. (2022), who reported 14 minutes. These results confirm that reductions in snoring time are reproducible across delivery formats. Because reduced snoring is mechanistically linked to improved tone of the tongue base and oropharyngeal musculature, these acoustic improvements support the observed gains in posterior IOPI strength. Both the analog and app groups trended downward in snore duration, indicating that the exercise protocol itself—rather than the delivery mode—is the primary factor driving improvement. These findings align with Li et al. (2025) and O'Connor-Reina (2024), who reported that strengthened airway muscle endurance reduces tissue vibration and improves perceived sleep quality.
Subjective outcomes followed similar trends. PROMIS Sleep Disturbance scores demonstrated a mean reduction of approximately 1.8 points, paralleling improvements documented in larger MFT cohorts (Rodríguez-Alcalá 2022; Navarro 2025) and sleep-focused behavioral programs (Buysse 2010; Roth 2018). ESS scores exhibited significant within-group improvements, indicating reduced daytime sleepiness following

daily MFT practice. The parallel improvement in objective parameters (AHI, IOPI, snoring acoustics) and subjective measures (ESS, PROMIS) reinforces the notion that neuromuscular improvements and perceived sleep benefits occur concurrently, a pattern also reported by Li et al. (2025) and O'Connor-Reina et al. (2024). NOSE and STOP-BANG scores did not change significantly, likely reflecting the short intervention duration or the limited sensitivity of these tools to detect subtle neuromuscular improvements.
Compliance played a key role in treatment response. Consistent with earlier pilot work, adherence was higher in the analog group compared with the app group. Although the Airway Gym app provides interactive features intended to increase engagement, some participants noted difficulty integrating app use into daily routines or navigating its interface. Despite these challenges, compliance in both groups far exceeded historical averages for unsupervised MFT (~10%; Guimarães 2009), demonstrating that structured guidance—regardless of format—substantially enhances adherence. The comparable physiologic improvements between groups indicate that when exercises are completed consistently, app-based delivery performs equivalently to traditional analog instructions.
Taken together, these findings demonstrate that MFT—whether administered digitally or through traditional instruction—produces meaningful short-term improvements in upper-airway muscle strength, nocturnal oxygenation patterns, snoring behavior, and subjective sleep quality in adults with mild to moderate OSA. The integration of digital home-monitoring tools such as the Belun Ring and SnoreLab represents a significant methodological advancement, enabling precise, repeated physiologic tracking in natural sleep environments. Nonetheless, several limitations must be acknowledged, including modest sample size, recruitment from limited geographic areas, and differing methods of adherence tracking between groups. Because OSA is multifactorial, involving craniofacial structure, neuromuscular tone, body weight, and ventilatory regulation, MFT alone cannot address all contributing factors. Future research would benefit from larger multicenter cohorts, standardized pre-treatment digital data collection, extended follow-up to evaluate long-term muscular adaptation, and continued refinement of app interfaces to facilitate user engagement. Overall, this study contributes to the growing body of evidence supporting MFT as an accessible, cost-effective, and physiologically grounded adjunctive treatment for OSA, with both analog and digital delivery formats demonstrating clinically meaningful benefits.

Were the results published?*

No

Have the results of this proposal been presented?*

No

To what extent have you used, or how do you intend to use, AAOF funding to further your career?*

As a professor, the AAOF funding I received allowed me to conduct this registered prospective randomized controlled trial. This was extremely productive not only for me, but also for the residents and junior faculty around, who got to see first-hand an AAOF project in action and got inspired to aim for something similar.

Accounting: Were there any leftover funds?

Not Published

Are there plans to publish? If not, why not?*

Yes, the manuscript is currently under preparation.

Not Presented

Are there plans to present? If not, why not?*

Yes, now that the project is complete, I intend to present the results in scientific meetings.

Internal Review

Reviewer comments

All specific aims were successfully completed. The study investigators are preparing a manuscript based on the results obtained. Final report is approved.

Reviewer Status*

Approved

File Attachment Summary

Applicant File Uploads

- Palomo AAOF BRA Data 2026 Final.pdf

The Effect of Technology for the Delivery of Myofunctional Exercises in OSA patients

Principal Investigator: Juan Martin Palomo DDS, MSD

Additional Investigators:
Brittney Sullivan DMD, MSD
Dan Yang DMD, MSD
Ambrose Chiang MD, FCCP, FAASM
Luciane Menezes DDS, MCS, PhD

Is there a difference in patients learning the exercises with a mobile device or from an analog piece of paper?

Is there a difference in patients learning the exercises with a mobile device or from an analog piece of paper? And is the increase in popularity of mobile health devices in healthcare actually creating a positive benefit for myofunctional therapy?

Objectives

1. To compare changes in airway strength and sleep-related metrics between patients performing myofunctional exercises using a smartphone application and those using a printed manual calendar over a three-month period.

2. To evaluate whether the mode of therapy delivery (app-based vs. analog) influences patient compliance and subjective sleep quality, as measured by validated instruments including the Epworth Sleepiness Scale and PROMIS Sleep Disturbance forms.

Hypothesis

H0: There is no statistically significant difference in treatment effects or compliance between app-based and analog delivery methods for myofunctional therapy in patients diagnosed with OSA after three months of intervention.

H0: There is no statistically significant difference in compliance between app-based and analog delivery methods for myofunctional therapy in patients diagnosed with OSA after three months of intervention.

H1: There are statistically significant differences in treatment effects and compliance between app-based and analog delivery methods for myofunctional therapy in patients diagnosed with OSA after three months of intervention.

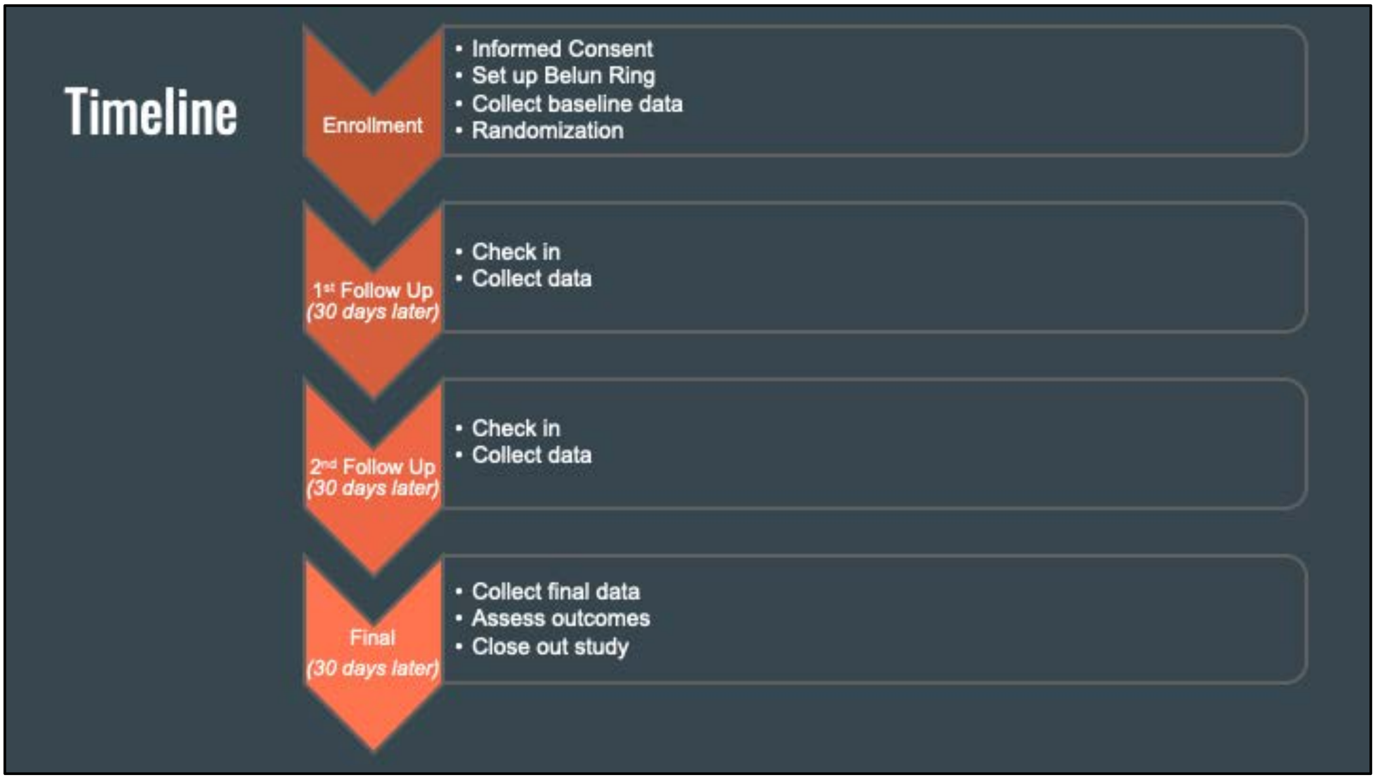
H1: There is statistically significant difference in compliance between app-based and analog delivery methods for myofunctional therapy in patients diagnosed with OSA after three months of intervention.

Materials and Methods

Prospective randomized controlled clinical study; multi-visit and non-blinded

INCLUSION CRITERIA

- Age range: from 18 to 75
- Recent PSG available
- BMI < 40
- No history of neuromuscular disease
- No restrictions in tongue movement that would prevent the subject to touch the roof of their mouth at any amount of mouth opening
- No history of alcohol or drug abuse
- No history of neuromuscular disease
- No chronic use of hypnotics
- No diagnosed temporomandi-bular joint disorder
- Must be able to present for follow up at all directed time points as per the protocol


Timeline
Enrollment
• Informed Consent
• Set up Belun Ring
• Collect baseline data
• Randomization
1st Follow Up
(30 days later)
• Check in
• Collect data
2nd Follow Up
(30 days later)
• Check in
• Collect data
Final
(30 days later)
• Collect final data
• Assess outcomes
• Close out study

Demographics

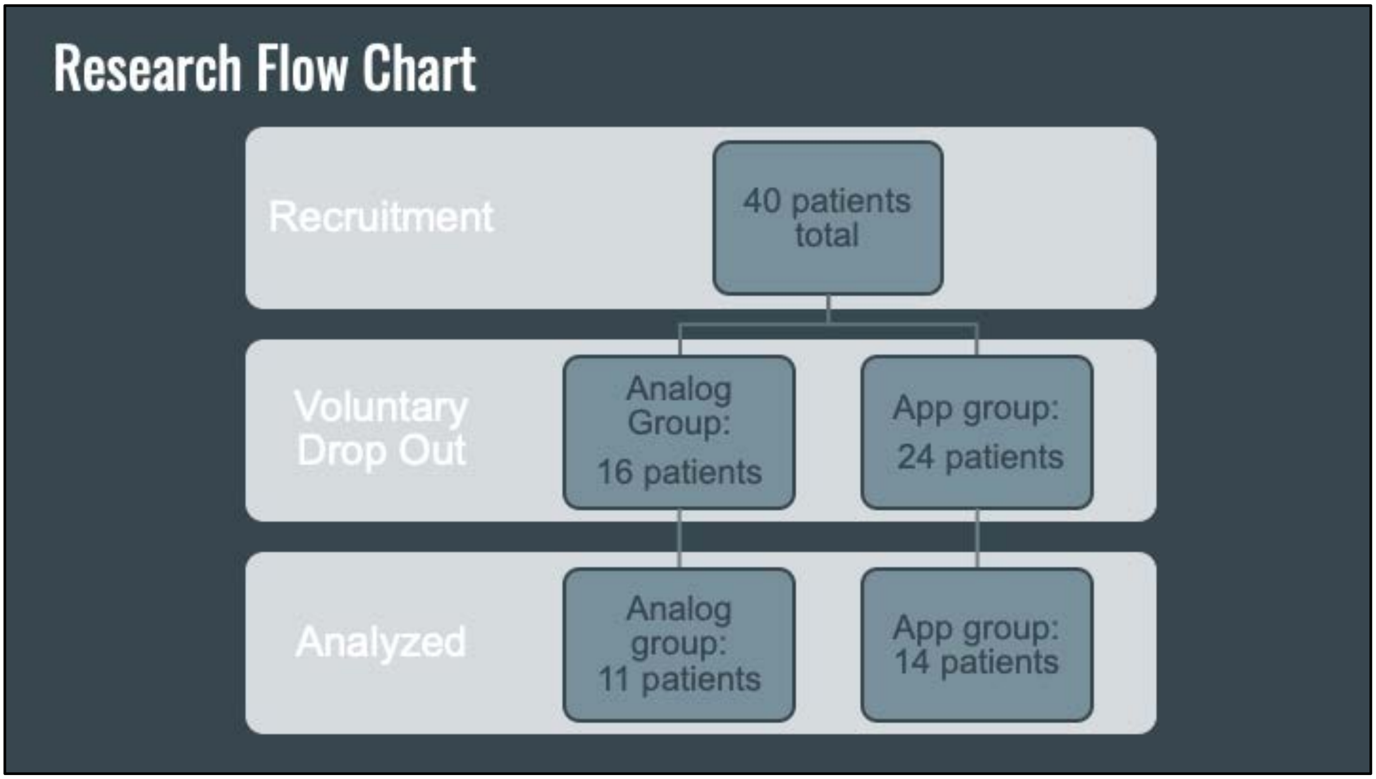
Variable	Analog (n=11)		Airway Gym (n=14)		P value
	Mean	STDEV	Mean	STDEV	
Age (yr), median (IQR)	62.50	9.62	54.80	14.06	0.13
Male	7		6		0.30
Female	4		8		
Mild Sleep Apnea	7		10		0.51
Moderate Sleep Apnea	3		2		
Severe Sleep Apnea	0		1		
Neck Circumference (in.), median(IQR)	16.01	1.76	15.48	1.45	0.42
Waist Circumference (in.), median (IQR)	43.41	3.71	41.84	6.45	0.48
BMI, median	32.82	7.12	31.55	8.48	0.70

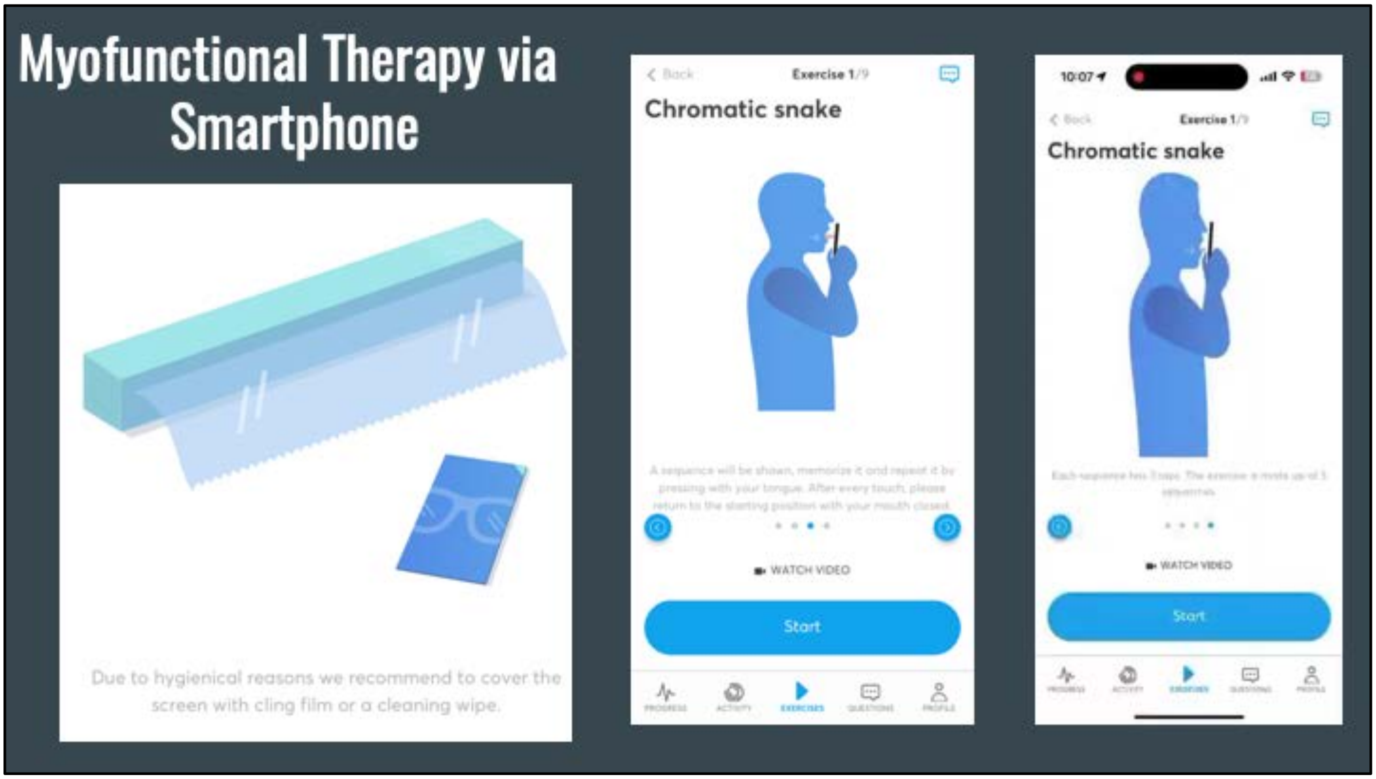
Required sample size per group: 9

$1 - \beta$

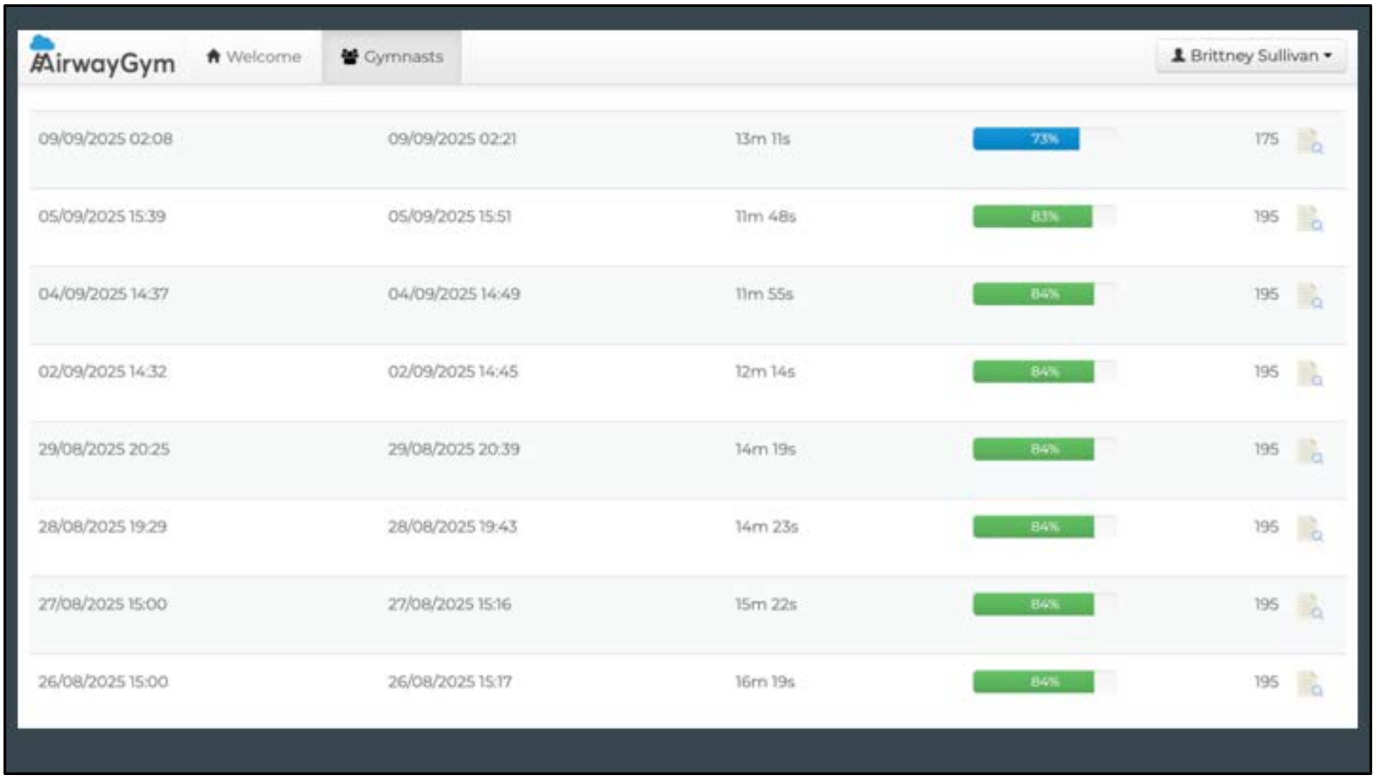
- Effect size d = 1.16 (large)
- Alpha = 0.05
- Power = 0.80
- Test: Two-sample t-test (two-tailed)
- Allocation: 1:1

Note: Total N = 18, inflate for dropout?


Research Flow Chart
Recruitment
40 patients total
Voluntary Drop Out
Analog Group:
16 patients
App group:
24 patients
Analyzed
Analog group:
11 patients
App group:
14 patients

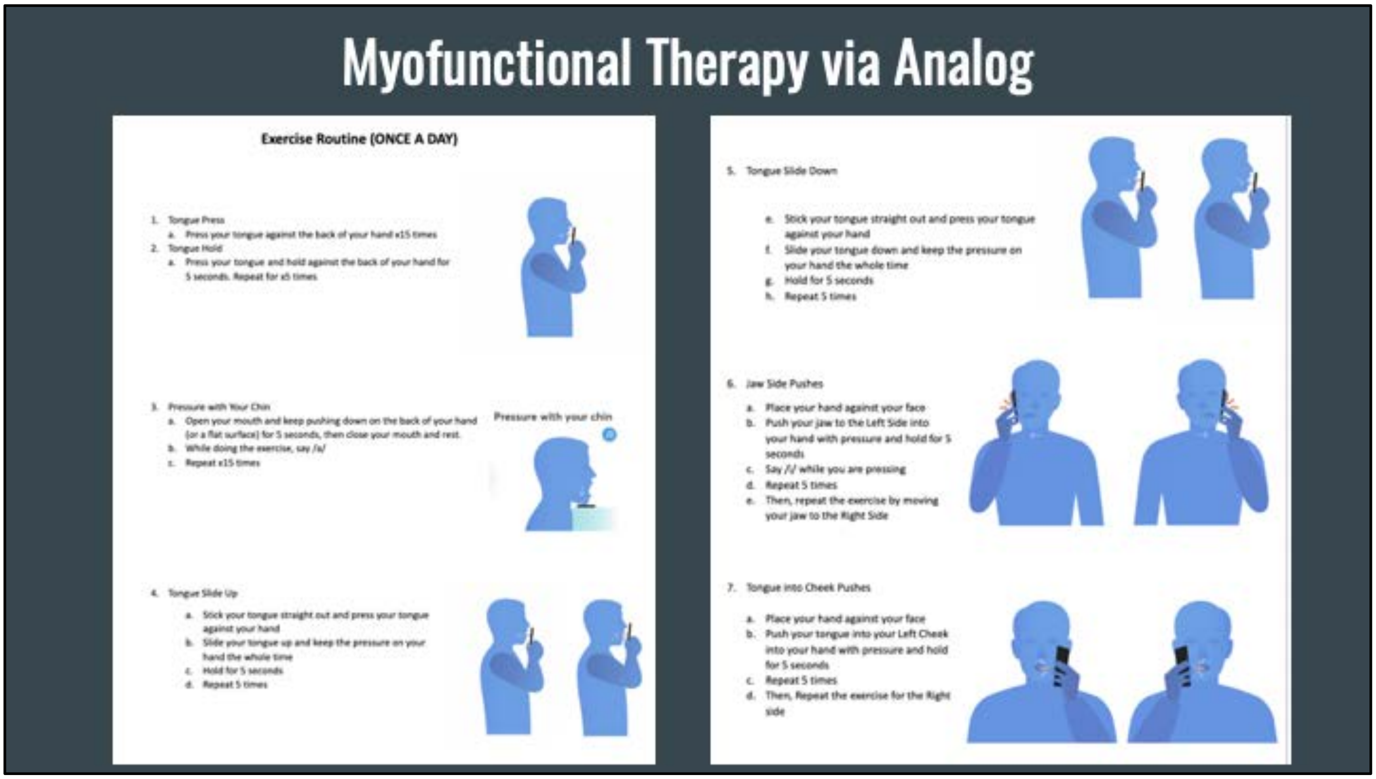


- Airway Gym is a smartphone application that groups in literature have used previously to assess various metrics of myofunctional therapy
- Total of 9 exercises which takes ~15-20mins a day to complete
- Initial session required to train the subject to use the app



AirwayGym | Welcome | Gymnasts | Brittney Sullivan

09/09/2025 02:08	09/09/2025 02:21	13m 11s	73%	175
05/09/2025 15:39	05/09/2025 15:51	11m 48s	83%	195
04/09/2025 14:37	04/09/2025 14:49	11m 55s	84%	195
02/09/2025 14:32	02/09/2025 14:45	12m 14s	84%	195
29/08/2025 20:25	29/08/2025 20:39	14m 19s	84%	195
28/08/2025 19:29	28/08/2025 19:43	14m 23s	84%	195
27/08/2025 15:00	27/08/2025 15:16	15m 22s	84%	195
26/08/2025 15:00	26/08/2025 15:17	16m 19s	84%	195


Myofunctional Therapy via Analog

Exercise Routine (ONCE A DAY)

1. Tongue Press
   a. Press your tongue against the back of your hand x15 times
2. Tongue Hold
   a. Press your tongue and hold against the back of your hand for 5 seconds. Repeat for x5 times
3. Pressure with Your Chin
   a. Open your mouth and keep pushing down on the back of your hand (or a flat surface) for 5 seconds, then close your mouth and rest.
   b. While doing the exercise, say /a/
   c. Repeat x15 times

Pressure with your chin

4. Tongue Slide Up
   a. Stick your tongue straight out and press your tongue against your hand
   b. Slide your tongue up and keep the pressure on your hand the whole time
   c. Hold for 5 seconds
   d. Repeat 5 times
5. Tongue Slide Down
   e. Stick your tongue straight out and press your tongue against your hand
   f. Slide your tongue down and keep the pressure on your hand the whole time
   g. Hold for 5 seconds
   h. Repeat 5 times
6. Jaw Side Pushes
   a. Place your hand against your face
   b. Push your jaw to the Left Side into your hand with pressure and hold for 5 seconds
   c. Say /i/ while you are pressing
   d. Repeat 5 times
   e. Then, repeat the exercise by moving your jaw to the Right Side
7. Tongue into Cheek Pushes
   a. Place your hand against your face
   b. Push your tongue into your Left Cheek into your hand with pressure and hold for 5 seconds
   c. Repeat 5 times
   d. Then, Repeat the exercise for the Right side

- Printed handout is delivered to all subjects
- Initial session required to review all exercises
- Identical exercises and written instructions from Airway Gym app

Myofunctional Therapeutic Exercises Compliance Form

Subject:

Appointment:

Day	Exercises completed (Y/N)	Exercise partially/not completed (Y/N)	Day	Exercises completed (Y/N)	Exercise partially/not completed (Y/N)
1			16		
2			17		
3			18		
4			19		
5			20		
6			21		
7			22		
8			23		
9			24		
10			25		
11			26		
12			27		
13			28		
14			29		
15			30		

Myofunctional Therapeutic Exercises Compliance Form

Subject:

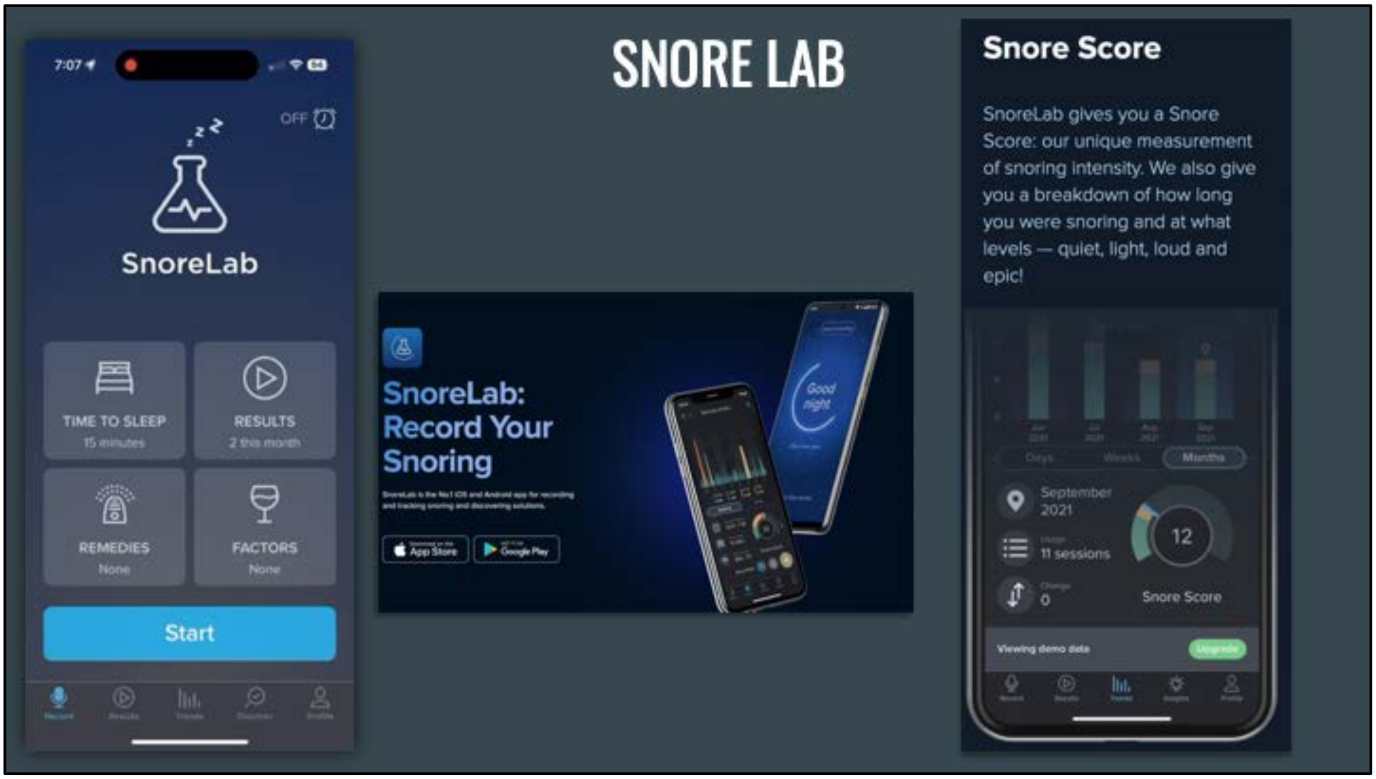
Appointment:

Day	Exercises completed (Y/N)	Exercise partially/not completed (Y/N)	Day	Exercises completed (Y/N)	Exercise partially/not completed (Y/N)
1 2.12.25	Y		16 2.27.25	Y	
2 2.13	Y		17 2.28.25	Y	
3 2-14	y		18 3-01-25	Y	
4 2-15	y		19 3-1-2-25	y	
5 2/16	y		20 3/3	y	
6 2/17	Y		21 3/4	y	
7 2/18	Y		22 3/5	y	
8 2-19	Y		23 3/6	Y	
9 2-20	Y		24 3/7	Y	
10 2-21-25	Y		25 3/8	Y	
11 2.22.25	Y		26 3-9	Y	
12 2.23	y		27 3-10	y	
13 2/24	y		28 3-11	y	
14 2/25	y		29 3-12	y	
15 2/26	y		30 3-13	Y	

3/14 Y
3/15 Y
3/16 Y

Muscles Involved in Myofunctional Therapy Exercises

Exercise	Muscles Involved
Chromatic Snake	Genioglossus, Hyoglossus, Styloglossus, Palatogloss
Snake Exercise	Genioglossus, Hyoglossus, Styloglossus, Palatogloss
Chin Pressure Exercise	Suprahyoid Group (Mylohyoid, Digastric, Geniohyoid, Stylohyoid), Platysma
Chameleon Up	Genioglossus, Superior Longitudinal
Chameleon Down	Genioglossus, Inferior Longitudinal
Tongue Left Cheek	Transverse Muscles of the Tongue, Buccinator
Tongue Right Cheek	Transverse Muscles of the Tongue, Buccinator
Right Mandibular Pressure	Masseter, Temporalis, Medial Pterygoid
Left Mandibular Pressure	Masseter, Temporalis, Medial Pterygoid



- Snore lab used to measure snoring the same nights as using the belun ring.
- We looked at Snore Score and Snore Duration
- The Snore Score is our unique measurement of snoring intensity. It doesn't have units that can be simplified to something like decibels because it is multi-dimensional. It takes into account snoring volume, duration and frequency. For example, a person who snores loudly for only a little portion of the night will score similarly to someone who snores quietly all night.

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ORIGINAL RESEARCH

Validation of Downloadable Mobile Snore Applications by Polysomnography (PSG)

Yi-Hsien Shiao[1,2], Chung-Chieh Yu[3], Yuan-Chieh Yeh[1,4]

Conclusion: These findings suggest that some parameters of free snore applications can be employed to monitor OSA progress, and future research could involve adjusted algorithms and larger-scale studies to further authenticate these downloadable snore and sleep applications.

Purpose: Obstructive sleep apnea (OSA) is a common breathing disorder during sleep that is associated with symptoms such as snoring, excessive daytime sleepiness, and breathing interruptions. Polysomnography (PSG) is the most reliable diagnostic test for OSA; however, its high cost and lengthy testing duration make it difficult to access for many patients. With the availability of free snore applications for home-monitoring, this study aimed to validate the top three ranked snore applications, namely SnoreLab (SL), Anti Snore Solution (ASS), and Sleep Cycle Alarm (SCA), using PSG.

Patients and Methods: Sixty participants underwent an overnight PSG while simultaneously using three identical smartphones with the tested apps to gather sleep and snoring data.

Results: The study discovered that all three applications were significantly correlated with the total recording time and snore counts of PSG, with ASS showing good agreement with snore counts. Furthermore, the Snore Score, Time Snoring of SL, and Sleep Quality of SCA had a significant correlation with the natural logarithm of apnea hypopnea index (lnAHI) of PSG. The Snore Score of SL and the Sleep Quality of SCA were shown to be useful for evaluating snore severity and for pre-diagnosing or predicting OSA above moderate levels.

Conclusion: These findings suggest that some parameters of free snore applications can be employed to monitor OSA progress, and future research could involve adjusted algorithms and larger-scale studies to further authenticate these downloadable snore and sleep applications.

Keywords: polysomnography, snoring, smartphone applications, apps, obstructive sleep apnea, apnea hypopnea index

- Validated medical grade wearable sensor that is positioned on the index finger
- Uses AI to calculate AHI, total sleep time, amount of time in each sleep stage
- Measures oxygen saturation, HR, HR variability
- Great correlation with PSG (R = 0.89)
- Patient instructed to wear ring for 3 nights without sleep aid devices and results were averaged

JCSM | Journal of Clinical Sleep Medicine

EMERGING TECHNOLOGIES

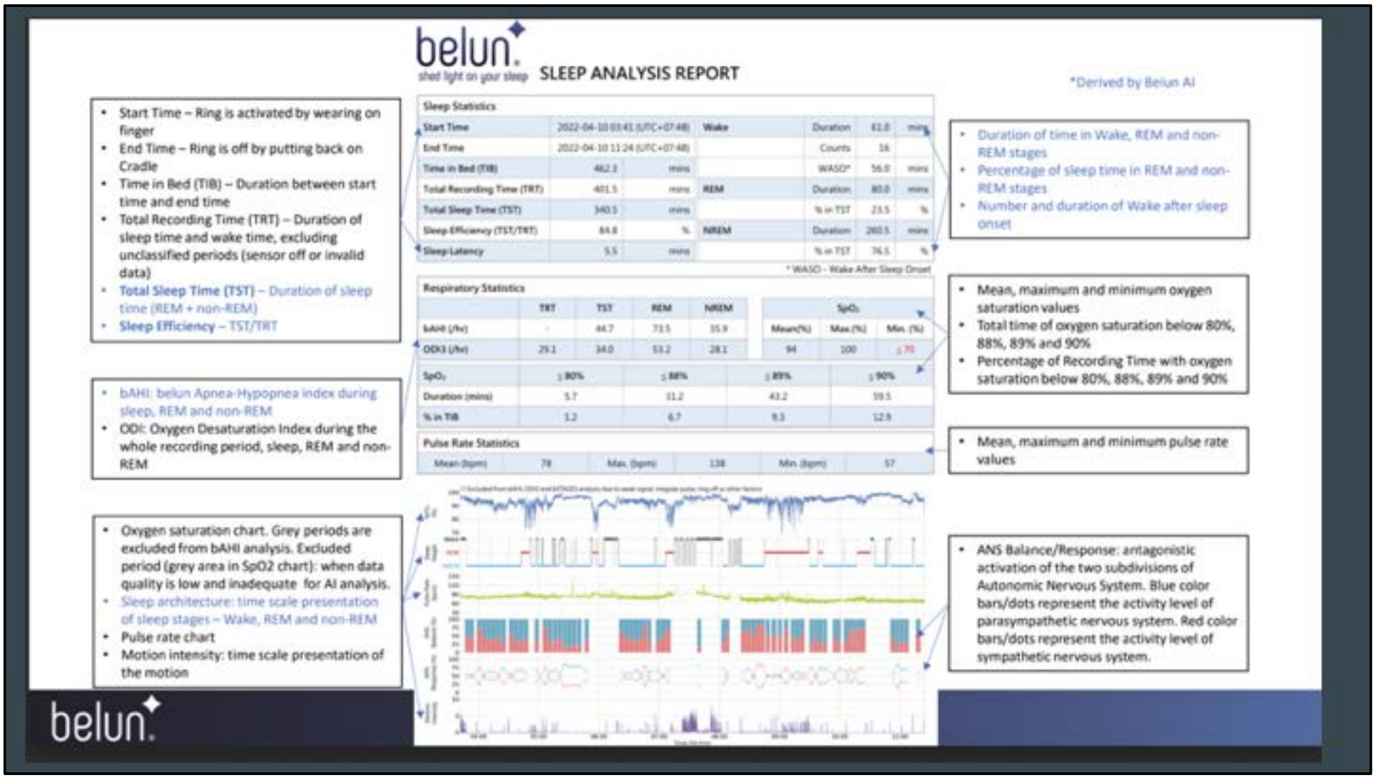
Belun Ring Platform: a novel home sleep apnea testing system for assessment of obstructive sleep apnea

Wenbo Gu, MPhil[1,2]; Lydia Leung, PhD[1]; Ka Cheung Kwok, PhD[1]; I-Chen Wu, PhD[2]; Rodney J. Folz, MD, PhD[3,4]; Ambrose A. Chiang, MD[3,4,5]

15 events/h. **Conclusions:** In this proof-of-concept study, the Belun Ring Platform demonstrated a reasonable accuracy in predicting AHI and total sleep time in patients without significant comorbidities and heart rate-affecting medications.

Study Objectives: The objective of the study is to validate the performance of Belun Ring Platform, a novel home sleep apnea testing system using a patented pulse oximeter sensor and a proprietary cloud-based neural networks algorithm.
Methods: The Belun Ring captures oxygen saturation, photoplethysmography, and accelerometer signals. The Belun Ring total sleep time is derived from features extracted from accelerometer, oxygen saturation, and photoplethysmography signals. The Belun Ring respiratory event index is derived from Belun Ring total sleep time and features extracted from heart rate variability and oxygen saturation changes. A total of 50 adults without significant cardiopulmonary or neuromuscular comorbidities and heart rate affecting medications were evaluated. In-lab sleep studies were performed simultaneously with the Ring and the studies were manually scored using the American Academy of Sleep Medicine Scoring Manual 4% desaturation criteria.
Results: The Belun Ring respiratory event index correlated well with the polysomnography-apnea-hypopnea index (AHI; $r = .894$, $P < .001$). The sensitivity and specificity in categorizing AHI ≥ 15 events/h were 0.85 and 0.87, respectively, and the positive predictive value and negative predictive value were 0.88 and 0.83, respectively. The Belun Ring total sleep time also correlated well with the polysomnography-total sleep time ($r = .945$, $P < .001$). Although the Belun Ring Platform has a good overall performance, it tends to overestimate AHI in individuals with AHI under 15 events/h and underestimate AHI in those with AHI over 15 events/h. **Conclusions:** In this proof-of-concept study, the Belun Ring Platform demonstrated a reasonable accuracy in predicting AHI and total sleep time in patients without significant comorbidities and heart rate-affecting medications.

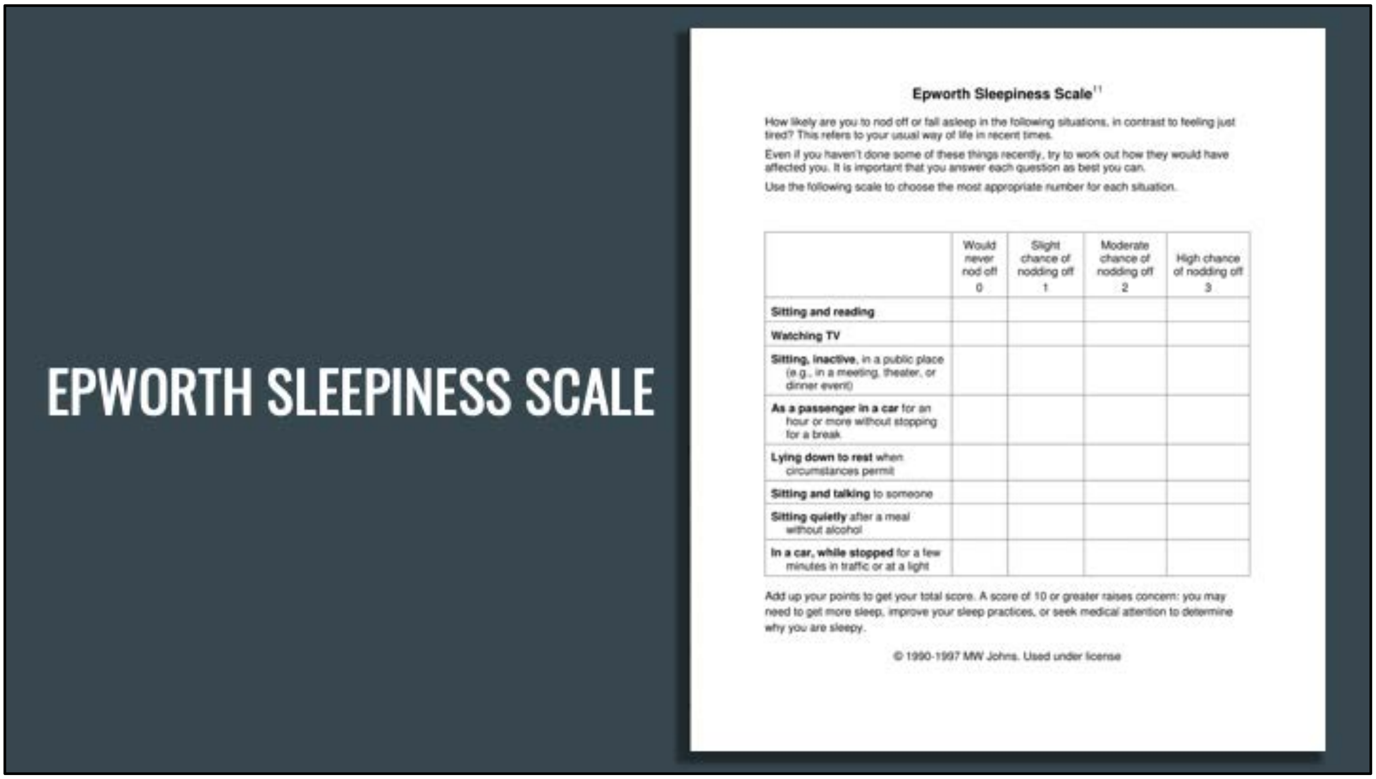
Clinical Trial Registration: Registry: ClinicalTrials.gov; Name: Validation of a Novel Device for Screening Patients With Symptoms of Obstructive Sleep Apnea; URL: https://clinicaltrials.gov/ct2/show/NCT04121923; Identifier: NCT04121923.
Keywords: obstructive sleep apnea, home sleep apnea testing, photoplethysmography
Citation: Gu W, Leung L, Kwok KC, Wu I-C, Folz RJ, Chiang AA. Belun Ring Platform: a novel home sleep apnea testing system for assessment of obstructive sleep apnea. *J Clin Sleep Med.* 2020;16(9):1611–1617.



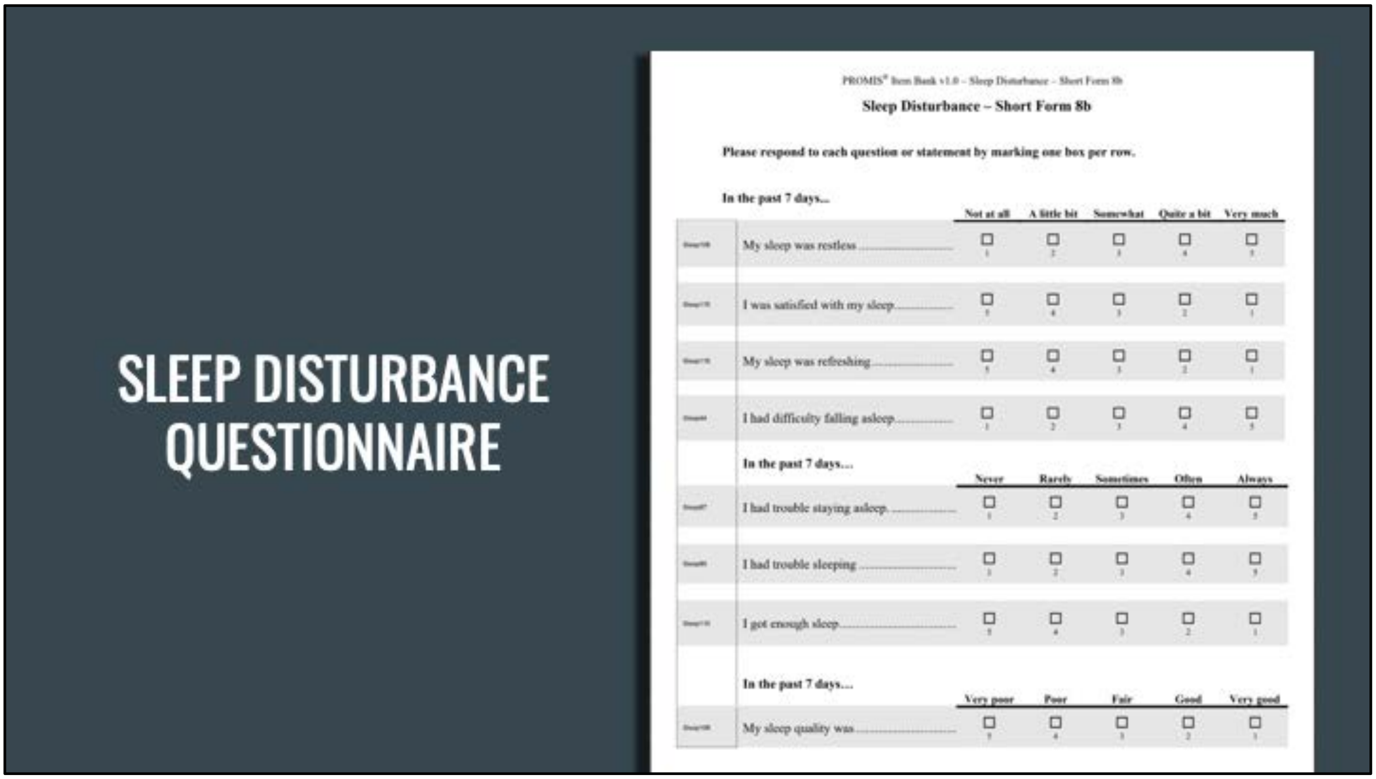
This is an example of a belun ring report

- In this study we looked at AHI which expresses the number of respiratory events per hour of actual sleep
- Sleep Efficiency which is a measurement of the total sleep time combining REM and non- REM sleep and total rest time which is the duration of sleep time and wake time excluding unclassified periods of the sensor off or invalid data. Indicates how well the subject slept; <85% = poor efficiency.
- **Mean SpO_2** shows general oxygenation throughout the night (normal is 95-100%)
- **Min SpO_2** highlights the most severe desaturation episode. (ideally above 90%)
- Average pulse rate - Increased variability may indicate arousals or sympathetic activation.

SURVEYS



The Epworth Sleepiness Scale measures subjective daytime sleepiness based on the likelihood of dozing in common daily activities.
It consists of 8 items scored from 0 to 3, with total scores ranging from 0–24.
Higher scores reflect greater excessive daytime sleepiness, which often correlates with higher AHI values or reduced sleep quality.



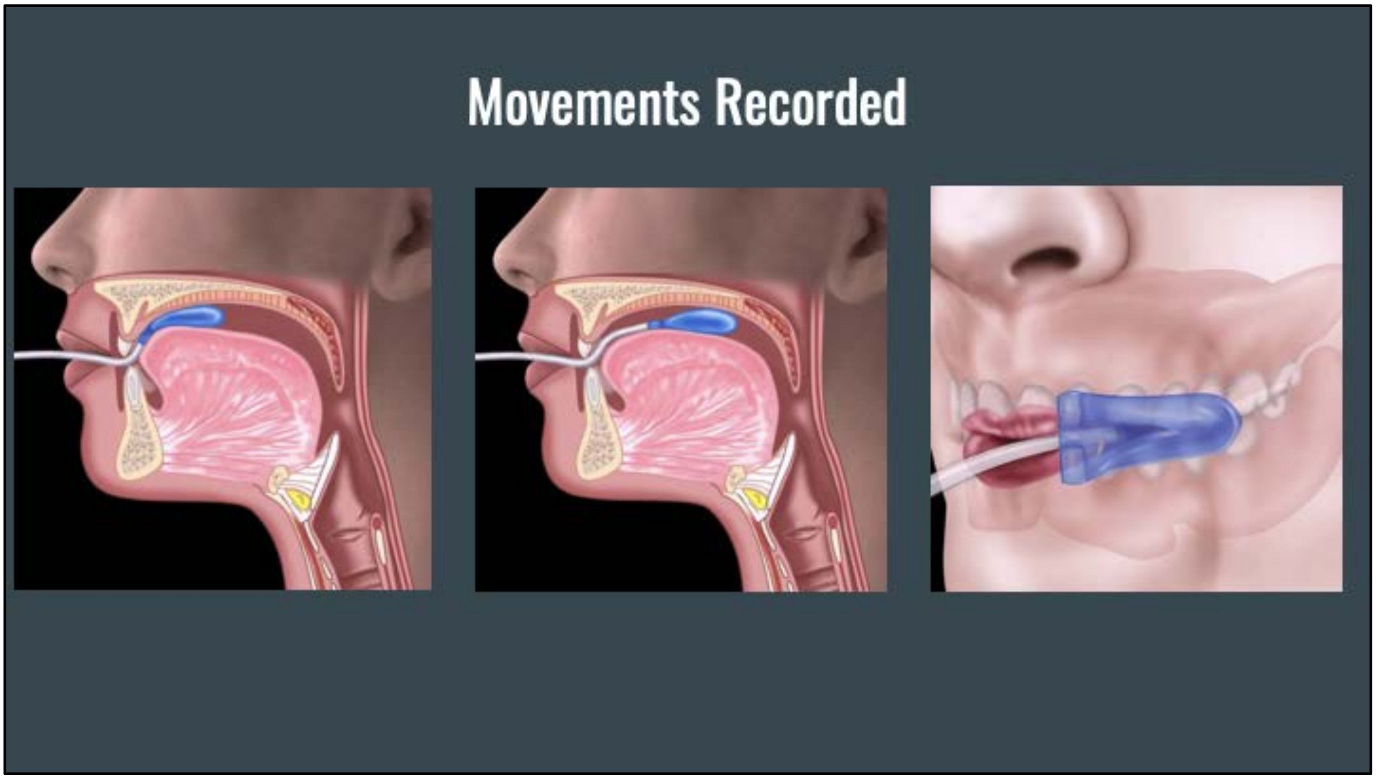
The PROMIS Sleep Disturbance questionnaire is a validated tool assessing the individual's perception of sleep quality over the past week.

Participants rate 8 items on a 5-point scale, and scores are converted to standardized T-scores.

Higher scores indicate greater sleep disturbance.

This helps correlate subjective sleep complaints with objective metrics like AHI and SpO_2 from the Belun Ring.

Iowa Oral Performance Instrument - The IOPI is an objective measurement tool that quantifies tongue and cheek strength in kilopascals.
Participants press an air-filled bulb with their tongue or cheek, and the device records the maximum pressure achieved.
We measured anterior, posterior, right, and left muscle groups to assess changes in orofacial strength after myofunctional therapy.



- Anterior: **Genioglossus** = pushes forward, **Superior longitudinal** = lifts the tip, **Intrinsic muscles (vertical + transverse)** = shape and stabilize
- **Posterior: Styloglossus + Palatoglossus** → elevation (especially posteriorly), **Superior longitudinal** → lifts the tip, **Vertical + transverse intrinsic** → flatten and widen the tongue, **Genioglossus** → stabilizes the base
- Buccinator R and L: **Buccinator** → compresses cheek and maintains pressure, **Orbicularis oris** → keeps lips sealed, **Tongue intrinsic/extrinsic muscles** → stabilize and balance suction forces, **Suprahyoid group** → supports the floor of mouth and pressure control.

RESULTS

Data Analysis

Normality testing: Shapiro–Wilk test used to assess data distribution

Within-group comparisons: Paired t-test or Wilcoxon Signed-Rank test (T1 vs T2 for each group)

Between-group comparisons: Independent t-test or Mann–Whitney U test (Analog vs App)

Categorical data: Chi-square test

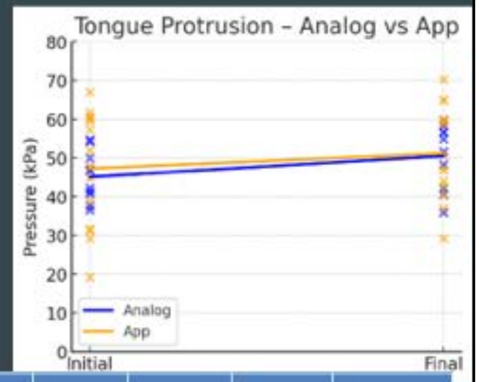
Inter-rater reliability: Intraclass Correlation Coefficient (ICC, two-way random, absolute agreement) for IOPI raters

Significance threshold: $p < 0.05$ considered statistically significant

Software: Data analyzed using SPSS

- We first checked for normality using the Shapiro–Wilk test.
  Depending on distribution, we ran paired *t*-tests or Wilcoxon tests within each group and independent *t*-tests or Mann–Whitney U tests between groups.
- Categorical variables were analyzed with Chi-square tests, and we used correlation analyses to explore relationships between muscle strength and sleep outcomes.
- Inter-rater reliability was assessed with ICC to confirm consistency among raters.
  A *p*-value below 0.05 was considered significant.

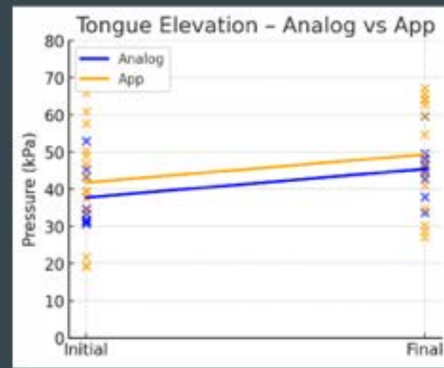
TONGUE PROTRUSION



Group	N	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	10	45.14	6.45	36.7 – 54.7	50.54	8.32	36.0 – 59.7	5.40	7.56	-4.7 – 20.6	0.0504	NS
App (n=14)	14	47.29	14.95	19.3 – 67.0	51.21	12.14	29.3 – 70.3	3.93	8.93	-7.0 – 21.0	0.1236	NS
All (n=24)	24	46.39	11.99	19.3 – 67.0	50.93	10.51	29.3 – 70.3	4.54	8.25	-7.0 – 21.0	0.0128	Significant

- This slide shows changes in anterior tongue strength, or tongue protrusion, measured by the IOPI.
- Both groups — analog in blue and app in orange — showed improvement from T1 to T2. The analog group increased by about 5.4 kPa on average, and the app group increased by about 3.9 kPa.
- When analyzed separately, neither group reached statistical significance — the analog group was borderline with a *p-value of 0.05*, and the app group had *p = 0.12*.
- However, when all 24 participants were analyzed together, the overall increase was statistically significant (*p = 0.0128*), indicating that the exercise program as a whole effectively strengthened the tongue, regardless of delivery method.
- It’s also interesting to note that the individual who demonstrated the greatest improvement — an increase of 21 kPa — was in the app group, showing that meaningful gains were achievable through remote, app-based training as well.

TONGUE ELEVATION

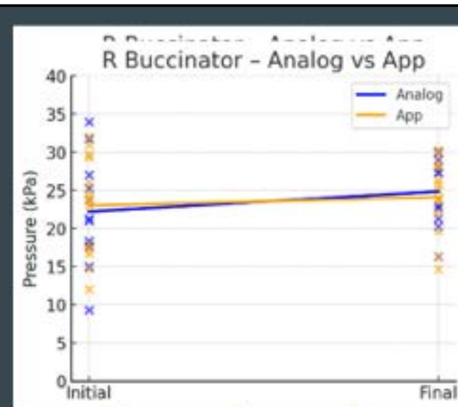


Group	N	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	10	37.76	7.84	30.7 – 53.0	45.44	6.96	33.7 – 59.7	7.68	9.94	-4.7 – 28.0	0.0372	Significant
App (n=14)	14	41.79	14.84	19.3 – 66.0	49.36	15.06	27.0 – 67.3	7.58	9.75	-8.0 – 27.6	0.0122	Significant
All (n=24)	24	40.11	12.35	19.3 – 66.0	47.73	12.29	27.0 – 67.3	7.62	9.62	-8.0 – 28.0	0.0008	Significant

- This slide shows changes in tongue elevation strength, which reflects posterior tongue function — an important muscle group for maintaining airway patency.
- Both the analog and app groups demonstrated statistically significant improvement from baseline to post-intervention.
- The analog group increased from a mean of 37.8 kPa to 45.4 kPa ($p = 0.037$), and the app group increased from 41.8 kPa to 49.4 kPa ($p = 0.012$).
- When all 24 participants were analyzed together, the overall improvement was highly significant ($p = 0.0008$).
- On average, participants improved by about 7.6 kPa, indicating that the exercise program effectively strengthened the posterior portion of the tongue across both delivery methods.
- These findings suggest that both app-based and analog training methods were equally effective in improving tongue elevation, which is particularly relevant for airway stability and swallowing function

Most: 28 analog

RIGHT BUCCINATOR



Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=11)	22.21	7.21	9.3 – 34.0	24.84	4.36	16.3 – 30.0	2.63	4.55	-4.4 – 8.0	0.0839	NS
App (n=14)	23.01	6.39	12.0 – 32.0	24.10	4.68	14.7 – 30.3	1.09	5.84	-10.0 – 11.0	0.4958	NS
All (n=25)	22.66	6.63	9.3 – 34.0	24.43	4.46	14.7 – 30.3	1.77	5.26	-10.0 – 11.0	0.1055	NS

- This slide shows changes in right buccinator strength, which reflects cheek muscle tone important for maintaining intraoral pressure and airway stability.
- The analog group increased from a mean of 22.2 kPa to 24.8 kPa, and the app group increased from 23.0 kPa to 24.1 kPa.
- Although both groups demonstrated small improvements, neither reached statistical significance — the analog group p-value was 0.084, and the app group p-value was 0.496.
- When all participants were analyzed together, the overall change also did not reach significance (*p = 0.106*).
- These results suggest that while buccinator strength trended upward, the changes were modest and variable, likely due to the smaller magnitude of improvement in cheek musculature compared to tongue exercises

Most: 11 App

LEFT BUCCINATOR

Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=11)	22.91	5.15	14.7 – 31.3	25.30	5.48	15.7 – 32.0	2.39	4.95	-5.6 – 10.6	0.1395	NS
App (n=14)	22.19	6.56	12.3 – 36.7	24.84	5.94	15.0 – 33.7	2.65	4.99	-5.0 – 9.7	0.0685	NS
All (n=25)	22.51	5.95	12.3 – 36.7	25.05	5.76	15.0 – 33.7	2.54	4.87	-5.6 – 10.6	0.0155	Significant

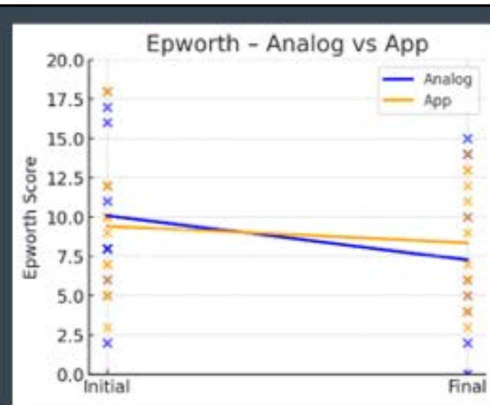
- This slide shows changes in left buccinator strength, reflecting cheek muscle tone on the opposite side.
- The analog group increased from 22.9 kPa to 25.3 kPa, and the app group increased from 22.2 kPa to 24.8 kPa.
- While both groups showed small improvements, neither reached statistical significance on their own — the analog group had $p = 0.14$ and the app group $p = 0.07$, which was trending toward significance.
- However, when all participants were analyzed together, the overall improvement became statistically significant ($p = 0.0155$), indicating that the myofunctional exercises produced measurable gains in left cheek strength when the groups were combined.
- Overall, both buccinator muscles trended upward, but the left side demonstrated a stronger overall response.

Inter-Rater Reliability (ICC, Two-Way Random, Absolute Agreement)

Measure Type	Raters (n)	ICC (A,1)	ICC (A,k)	Interpretation
Combined T1 & T2 Averages (All Categories)	3	0.997	0.999	Excellent

- Before analyzing results, we wanted to make sure that all three raters were measuring the IOPI readings consistently.
- To do that, we ran an inter-rater reliability test using the intraclass correlation coefficient, or ICC.
- We used a two-way random-effects model that looks at absolute agreement — basically, it tests how similar the raters' scores are to each other.
- After averaging all T1 and T2 measurements for each muscle group, the ICC for a single rater was 0.997, and when we averaged across all three raters it was 0.999.
- These values are considered excellent reliability, meaning there was almost no difference between raters.

Epworth

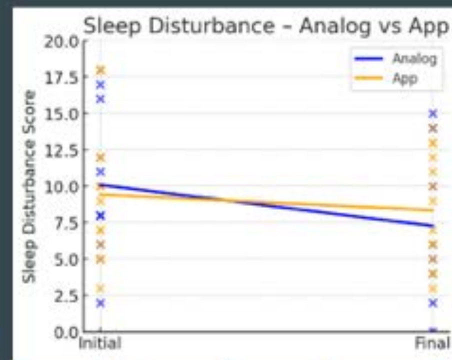


Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=11)	10.09	5.20	2.0 – 18.0	7.27	5.18	0.0 – 15.0	-2.82	2.93	-7.0 – 3.0	0.0096	Significant
App (n=14)	9.43	4.52	3.0 – 18.0	8.36	3.82	3.0 – 14.0	-1.07	2.95	-6.0 – 3.0	0.1969	NS
All (n=25)	9.72	4.74	2.0 – 18.0	7.88	4.40	0.0 – 15.0	-1.84	3.01	-7.0 – 3.0	0.0054	Significant

- This slide shows the results from the Epworth Sleepiness Scale, which measures daytime sleepiness based on the likelihood of dozing off in different daily situations.
- The analog group showed a significant reduction in sleepiness, decreasing from an average score of 10.1 to 7.3 ($p = 0.0096$).
- The app group also showed improvement, decreasing from 9.4 to 8.4, though this change did not reach statistical significance ($p = 0.20$).
- When all participants were analyzed together, the overall decrease was statistically significant ($p = 0.0054$), with a mean reduction of 1.84 points.
- This indicates that participants—especially in the analog group—experienced less daytime sleepiness after completing the myofunctional therapy program, consistent with improved airway function and sleep quality

Most: -7 analog

SLEEP DISTURBANCE

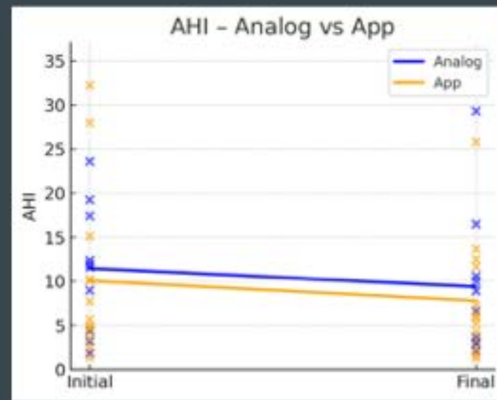


Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=11)	10.09	5.20	2.0 – 18.0	7.27	5.18	0.0 – 15.0	-2.82	2.93	-7.0 – 3.0	0.0096	Significant
App (n=14)	9.43	4.52	3.0 – 18.0	8.36	3.82	3.0 – 14.0	-1.07	2.95	-6.0 – 3.0	0.1969	NS
All (n=25)	9.72	4.74	2.0 – 18.0	7.88	4.40	0.0 – 15.0	-1.84	3.01	-7.0 – 3.0	0.0054	Significant

- This slide shows results from the PROMIS Sleep Disturbance Short Form, which measures perceived sleep quality, restfulness, and difficulty falling or staying asleep.
- The analog group demonstrated a significant improvement, with scores decreasing from 10.1 to 7.3 (*p = 0.0096*), indicating fewer sleep disturbances after therapy.
- The app group also showed a reduction from 9.4 to 8.4, although this change did not reach statistical significance (*p = 0.20*).
- When all participants were analyzed together, the overall reduction was statistically significant (*p = 0.0054*).
- This suggests that participants generally perceived better sleep quality and less disturbance following myofunctional therapy, especially among those in the analog group

Most: -17 Analog

AHI



Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	11.47	7.16	1.90 – 23.60	9.39	8.32	2.10 – 29.30	-2.08	4.84	-9.88 – 5.70	0.2078	NS
App (n=13)	10.06	9.67	1.40 – 32.20	7.80	6.77	1.33 – 25.80	-2.26	5.42	-14.30 – 7.00	0.1591	NS
All (n=23)	10.67	8.51	1.40 – 32.20	8.49	7.34	1.33 – 29.30	-2.18	5.06	-14.30 – 7.00	0.0510	NS

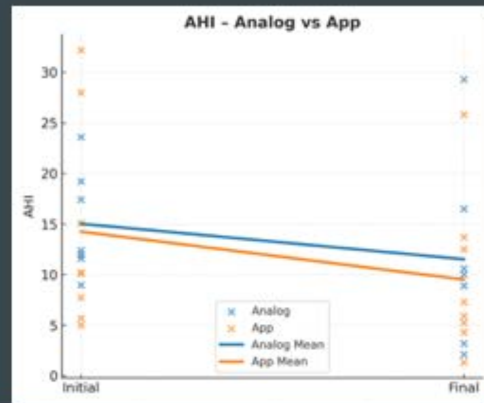
- This first analysis includes all 23 participants.
- You'll notice both groups had a small decrease in AHI—about 2 events per hour on average—but the results weren't statistically significant.
- However, since some participants had a baseline AHI below 5, which is considered normal and not diagnostic of OSA, we re-ran the analysis excluding those patients to better isolate the treatment effect in true OSA cases.

Group	T1	T2	Change	% Change
Analog	17.44	10.03	-7.41	-42.49
Analog	11.98	2.1	-9.88	-82.47
Analog	11.6	8.9	-2.7	-23.28
Analog	12.4	10.6	-1.8	-14.52
Analog	23.6	29.3	5.7	24.15
Analog	1.9	3.7	1.8	94.74
Analog	3.18	6.67	3.49	109.75
Analog	19.25	16.5	-2.75	-14.29
Analog	8.97	3.2	-5.77	-64.33
Analog	4.35	2.9	-1.45	-33.33
App	4.6	6.2	1.6	34.78
App	15.1	5.9	-9.2	-60.93
App	10.1	12.51	2.41	23.86
App	7.73	5.25	-2.48	-32.08
App	5	1.33	-3.67	-73.40
App	32.2	25.8	-6.4	-19.88
App	4.7	11.7	7	148.94
App	10.2	7.3	-2.9	-28.43
App	3.5	2.4	-1.1	-31.43
App	5.7	4.3	-1.4	-24.56
App	2.5	3.3	0.8	32.00
App	28	13.7	-14.3	-51.07
App	1.4	1.68	0.28	20.00

Group	T1	T2	Change	% Change
Analog	17.44	10.03	-7.41	-42.49
Analog	11.98	2.1	-9.88	-82.47
Analog	11.6	8.9	-2.7	-23.28
Analog	12.4	10.6	-1.8	-14.52
Analog	23.6	29.3	5.7	24.15
Analog			1.8	94.74
Analog			3.49	109.75
Analog	19.25	16.5	-2.75	-14.29
Analog	8.97	3.2	-5.77	-64.33
Analog			-1.45	-33.33
App			1.6	34.78
App	15.1	5.9	-9.2	-60.93
App	10.1	12.51	2.41	23.86
App	7.73	5.25	-2.48	-32.08
App	5	1.33	-3.67	-73.40
App	32.2	25.8	-6.4	-19.88
App			7	148.94
App	10.2	7.3	-2.9	-28.43
App			-1.1	-31.43
App	5.7	4.3	-1.4	-24.56
App			0.8	32.00
App	28	13.7	-14.3	-51.07
App			0.28	20.00

- For this analysis, we excluded patients whose baseline AHI was below 5, since that's considered within the normal range and wouldn't reflect clinically significant sleep apnea.
- The table shows each participant's change from T1 to T2, and the yellow highlights represent individuals who showed more than a 50% change in AHI
- This helps us visualize individual variability and identify strong responders to therapy, while focusing on participants who actually met the OSA diagnostic threshold.

AHI greater than 5 initial AHI



Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n = 7)	15.03	5.19	9.0 – 23.6	11.52	9.21	2.1 – 29.3	-3.52	5.00	-9.9 – 5.7	0.1121	NS
App (n = 8)	14.25	10.33	5.0 – 32.2	9.51	7.76	1.3 – 25.8	-4.74	5.15	-14.3 – 2.4	0.0353	Significant
All (n = 15)	14.62	8.07	5.0 – 32.2	10.45	8.22	1.3 – 29.3	-4.17	4.94	-14.3 – 5.7	0.0056	Significant

- This graph shows the change in Apnea–Hypopnea Index (AHI) for participants with an initial AHI greater than 5, comparing the analog and app groups.
- The analog group is shown in blue and the app group in orange, with individual data points and mean trend lines.
- Both groups demonstrated a reduction in AHI from baseline to post-intervention, indicating fewer apnea and hypopnea events after completing the myofunctional therapy program.
- The app group showed a slightly greater average reduction, from about 14 to 9.5 events per hour, compared to the analog group's decrease from 15 to 11.5.
- Statistically, this reduction was significant for the app group ($p = 0.035$) and highly significant when all participants were analyzed together ($p = 0.0056$).
- This demonstrates that both delivery methods were effective, but the app-based group achieved slightly larger improvements in sleep apnea severity

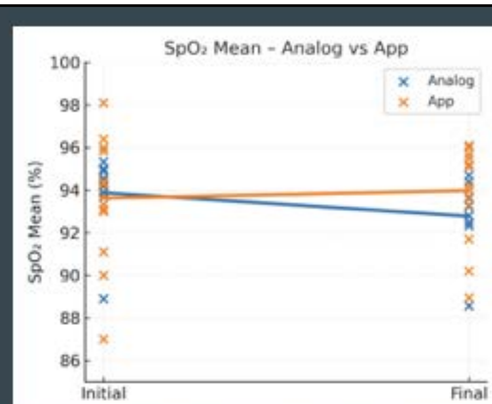
SpO2 Minimum

Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	80.76	6.08	72.5–92.8	80.26	4.67	71.5–85.3	-0.50	3.60	-8.7–4.6	0.6707	NS
App (n=14)	80.20	6.09	70.0–89.9	81.00	6.46	70.8–90.5	+0.80	7.47	-8.6–20.5	0.6961	NS
All (n=24)	80.43	5.96	70.0–92.8	80.69	5.68	70.8–90.5	+0.26	6.08	-8.7–20.5	0.8381	NS

- This slide shows the minimum oxygen saturation (SpO_2 minimum) during sleep, comparing the analog and app groups.
- In both groups, the lowest oxygen saturation levels remained relatively stable from pre- to post-intervention.
- The analog group changed slightly from 80.8% to 80.3%, and the app group increased from 80.2% to 81.0%, neither reaching statistical significance.
- The combined group mean change was minimal — only +0.26% ($p = 0.84$).
- This indicates that while participants' airway events improved, their oxygen levels during the most desaturated periods did not change significantly, suggesting that oxygenation was preserved throughout the study.

Most: -8.6 App

SpO2 Mean

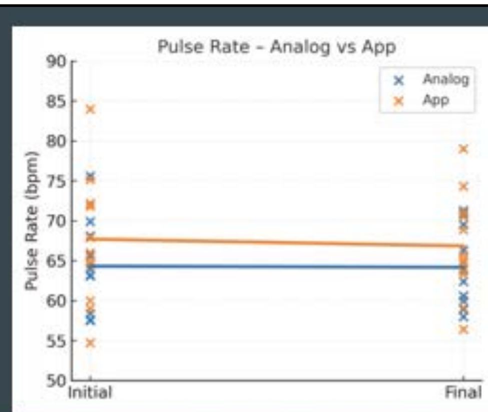


Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=9)	93.88	1.94	88.9–95.33	92.78	1.78	88.57–94.7	-1.1	0.91	-2.53–0.2	0.0067	Significant
App (n=14)	93.62	2.83	87.0–98.1	93.98	2.25	88.95–96.1	0.35	2.85	-4.05–6.1	0.6498	NS
All (n=23)	93.72	2.47	87.0–98.1	93.51	2.12	88.57–96.1	-0.22	2.37	-4.05–6.1	0.6674	NS

- This slide shows the mean oxygen saturation (SpO_2 Mean) during sleep for both groups.
- The analog group showed a slight decrease in average oxygen levels from 93.9% to 92.8%, which was statistically significant (*p = 0.0067*), but this difference is small — roughly a 1% drop and likely not clinically meaningful.
- The app group, in contrast, showed a minor increase from 93.6% to 94.0%, which was not significant.
- When combining all participants, the overall change was negligible (*p = 0.67*).
- So, while the analog group reached statistical significance, these small differences likely reflect normal nightly variation rather than true physiological decline, indicating that oxygenation remained overall stable throughout the study

Most: 6.1 App

Pulse Rate

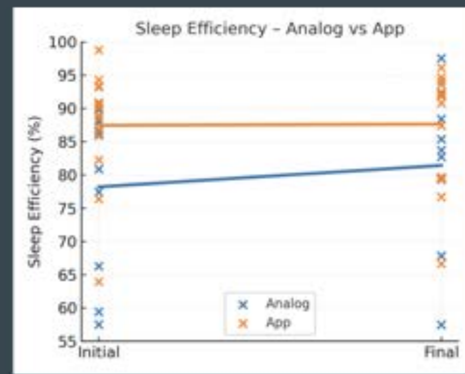


Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	64.31	5.81	57.51–75.63	64.16	5.03	58.0–71.3	-0.15	3.45	-6.13–4.75	0.8964	NS
App (n=12)	67.7	7.99	54.72–84.0	66.85	6.31	56.4–79.0	-0.85	4.53	-8.9–6.13	0.5274	NS
All (n=22)	66.16	7.13	54.72–84.0	65.63	5.79	56.4–79.0	-0.53	4.0	-8.9–6.13	0.5392	NS

- This slide shows average pulse rate recorded overnight before and after the intervention.
- Both the analog and app groups demonstrated very minimal changes. The analog group decreased slightly from 64.3 to 64.2 beats per minute, and the app group from 67.7 to 66.9, neither of which were statistically significant ($p > 0.5$ for both).
- When all participants were analyzed together, the overall change was less than one beat per minute, indicating no meaningful difference in pulse rate after completing the myofunctional therapy program.
- This suggests that while sleep-disordered breathing improved, autonomic function remained stable, meaning there was no increase in sympathetic activation or cardiovascular strain.

Most: decrease 8.9 App

Sleep Efficiency



Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	78.21	12.61	57.51–89.87	81.43	11.64	57.47–97.55	3.22	11.89	-8.83–30.91	0.4137	NS
App (n=14)	87.45	8.69	63.93–98.8	87.64	8.67	66.66–96.1	0.2	11.51	-13.55–32.17	0.9499	NS
All (n=24)	83.6	11.25	57.51–98.8	85.06	10.26	57.47–97.55	1.46	11.51	-13.55–32.17	0.5413	NS

- This slide shows sleep efficiency, or the percentage of time in bed actually spent sleeping.
- The analog group increased slightly from 78.2% to 81.4%, and the app group remained stable at around 87.5% before and after the intervention.
- The overall mean change was +1.46%, which was not statistically significant (*p = 0.54*).
- These results suggest that while the intervention did not significantly alter overall sleep efficiency, it also did not negatively affect sleep architecture — meaning participants maintained consistent sleep quality and duration while showing improvements in AHI and muscle strength

Increased 32.17 App

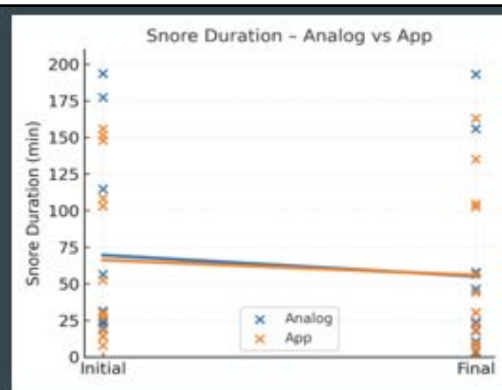
Snore Score

Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	29.45	16.71	4.33–57.51	20.45	12.85	2.29–38.68	-9.0	10.78	-35.76–3.5	0.0269	Significant
App (n=13)	32.37	20.19	9.0–79.76	30.45	24.68	3.39–90.3	-1.93	11.06	-27.71–15.0	0.5415	NS
All (n=23)	31.1	18.41	4.33–79.76	26.1	20.63	2.29–90.3	-5.0	11.27	-35.76–15.0	0.0448	Significant

- This slide shows changes in snore score, which quantifies both the intensity and duration of snoring events as measured by SnoreLab.
- The analog group showed a significant reduction from 29.5 to 20.5 (*p = 0.0269*), indicating less snoring after therapy.
- The app group also demonstrated a small decrease from 32.4 to 30.5, though this change was not statistically significant (*p = 0.54*).
- When combining all participants, there was a significant overall reduction in snore score (*p = 0.0448*).
- These findings suggest that myofunctional therapy led to measurable improvement in snoring, particularly among those performing the analog version of the exercises

Decreased 35.75 App

Snore Duration



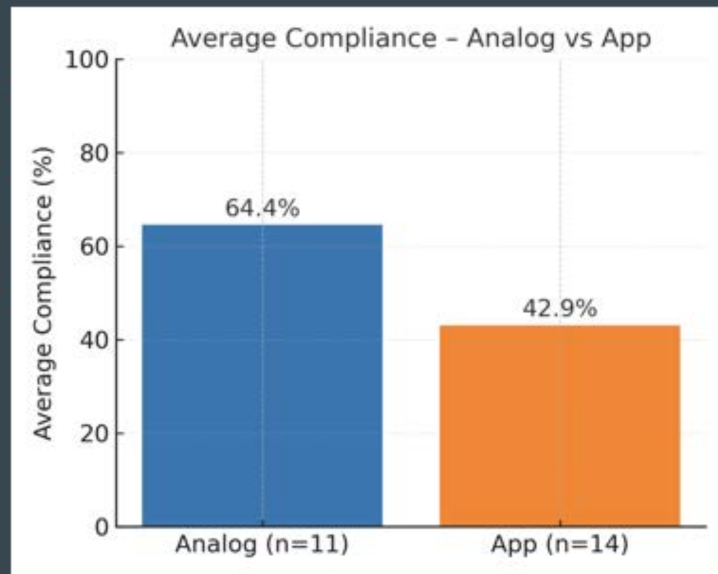
Group	Mean T1	SD T1	Range T1	Mean T2	SD T2	Range T2	Mean Δ	SD Δ	Range Δ	P value	Significance
Analog (n=10)	69.6	67.44	19.67–193.67	55.17	65.52	4.0–193.25	-14.43	20.58	-56.78–15.92	0.0538	NS
App (n=13)	66.28	58.14	8.0–155.86	55.96	52.89	3.0–163.0	-10.33	20.41	-53.36–11.41	0.093	NS
All (n=23)	67.72	60.89	8.0–193.67	55.61	57.29	3.0–193.25	-12.11	20.12	-56.78–15.92	0.0085	Significant

- This slide shows snore duration, or the total number of minutes participants spent snoring overnight.
- Both groups showed a decrease in snoring time after the intervention. The analog group decreased from 69.6 minutes to 55.2 minutes, and the app group from 66.3 to 56.0 minutes.
- While these reductions were not individually significant (*p = 0.05 for analog, p = 0.09 for app*), when all participants were analyzed together, there was a significant overall reduction in snoring duration (*p = 0.0085*).
- This demonstrates that myofunctional therapy effectively reduced total snoring time, even though the results by delivery method did not differ significantly.

Decreased 56.78 analog

Compliance

Group	Mean (%)	SD (%)	Range (%)	P value (Analog vs App)	Significance
Analog	64.4	17.1	39–88		
App	42.9	22.4	9–79		
All	52.3	22.6	9–88	0.0121	S



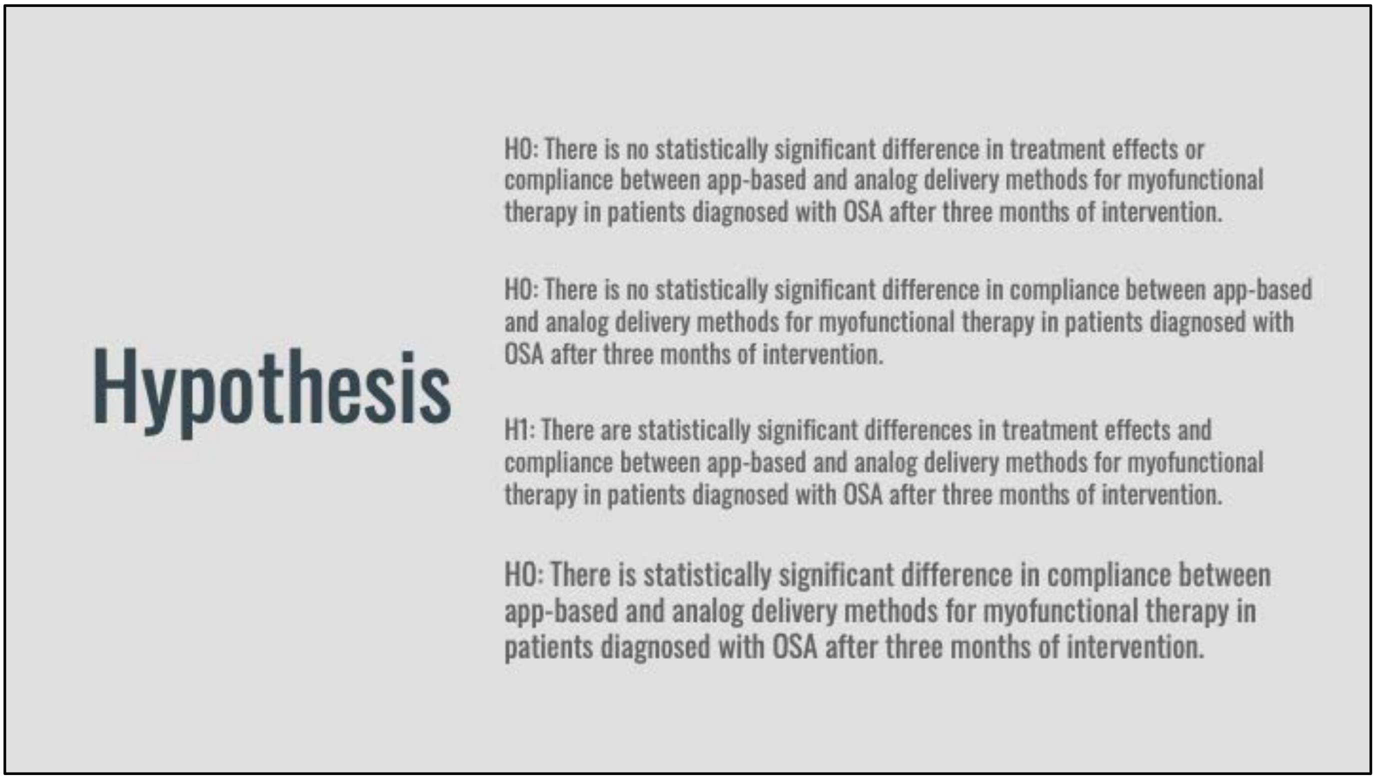
- This slide compares average compliance between the analog and app groups.
- Compliance was measured as the percentage of prescribed exercises completed during the intervention period.
- The analog group demonstrated significantly higher adherence, averaging 64.4%, compared to 42.9% in the app group (*p = 0.0121*).
- This difference is statistically significant, suggesting that participants who received in-person, paper-based instructions were more consistent with their exercises than those using the mobile app.
- This likely contributed to the greater improvements in muscle strength, AHI, and snoring observed in the analog group.

Measure	Analog	App	Total
Anterior IOPI			*
Posterior IOPI	*	*	*
L IOPI			*
R IOPI			
Pulse Rate			
SpO_2 Min			
SpO_2 Mean	*		
Sleep Efficiency			
Epworth	*		*
Snore Score	*		*
Snore Duration			*
AHI		*	*
Sleep Disturbance	*		*

8/13

TOTAL SIGNIFICANT

- Out of thirteen total outcome measures, eight showed statistically significant improvement, either within individual groups or when all participants were combined.
- Both groups demonstrated significant increases in posterior tongue strength, while the analog group alone showed additional improvements in mean oxygen saturation, Epworth scores, and snore score.
- When all participants were analyzed together, there were significant improvements in anterior and posterior tongue strength, left buccinator strength, AHI, snore duration, sleep disturbance, and overall snore score.
- These results indicate that myofunctional therapy led to measurable improvements in airway muscle function and sleep quality, with slightly stronger effects seen in participants who completed the analog exercise program



- Our primary hypothesis aimed to determine whether the method of delivering myofunctional therapy — either app-based or analog — would impact treatment outcomes or patient compliance.
- The null hypothesis (H_0) stated that there would be no statistically significant differences between the two groups in either treatment effects or compliance after three months.
- The alternative hypothesis (H_1) proposed that there would be significant differences between the groups.
- Based on the results, we found that treatment effects were not significantly different between delivery methods — supporting the null hypothesis for outcomes. However, compliance was significantly higher in the analog group, leading us to reject the null hypothesis for compliance.

DISCUSSION IOPI

- Our baseline and post-treatment IOPI values (46 → 51 kPa) fall within the expected range reported in the literature (35–60 kPa, *Navarro 2025, Rodriguez-Alcalá 2022, Li 2025*) and align with mild-to-moderate hypotonic range. This confirms that our participants' tongue strength was comparable to other OSA populations before and after MFT intervention. IOPI values in OSA patients typically range 30–60 kPa, lower than healthy adults (~65–70 kPa *Clark 2012; Adams 2013*).

- Post-intervention values (~51 kPa) approach those of non-hypotonic or compensated OSA phenotypes described by Navarro et al.

- The magnitude of improvement (~4–5 kPa) is clinically consistent with prior studies, supporting reproducibility of strength gains. *(Rodriguez-Alcalá 2022; Li 2025; Navarro 2025)*

-Although not all IOPI outcomes reached statistical significance, the direction of change was consistent across all measures. These results mirror prior findings showing that myofunctional therapy increases tongue and orofacial muscle strength.

-Improvements in tongue pressure indicate enhanced activation of the genioglossus and related airway muscles, contributing to improved airway tone.

-Results suggest that orofacial strength training is a viable adjunctive therapy for OSA management across delivery formats.

- Reinforces that even modest absolute increases (≈ 5 kPa) can correspond with improved airway stability and reduced AHI, as observed in our results.

DISCUSSION SURVEYS

~ Our PROMIS reduction (–1.8 points) parallels the magnitude seen in larger MFT *(Rodríguez-Alcalá 2022; Navarro 2025)* and behavioral-therapy trials *(Buysse 2010; Roth 2018)*

~ Suggests fewer nighttime awakenings and improved restfulness

~ Reinforces that both objective improvements (AHI, IOPI) and subjective improvements (ESS, PROMIS) occurred concurrently

- Aligns with Li et al. (2025) and O’Connor Reina et al. (2024), confirming that subjective benefit accompanies physiological improvement

DISCUSSION BELUN RING FINDINGS

~ Consistent with O'Connor Reina et al., 2024, Li et al., 2025, Rodríguez-Alcalá et al., 2022, Guimarães et al., 2009 our study also showed a significant decrease in AHI Confirms that both analog and app-based delivery modes effectively reduce airway obstruction events

~ SpO2 Mean and minimum remaining stable is consistent with Li et al. (2025), who found improved breathing events without significant desaturation change

~ Pulse Rate: unchanged in both groups, confirming no increase in sympathetic activity or sleep fragmentation

~ Sleep efficiency in our study remains stable which mirrors Bui-Diem et al. (2023) and Goswami et al. (2019) findings, where patients reported improved perceived sleep quality even when objective efficiency remained unchanged. Suggests that MFT enhances sleep quality through reduced respiratory arousals, not by altering total sleep time

DISCUSSION SNORE LAB FINDINGS

~ Our study had an overall average decease of snore duration by 12 minutes. This is consistent with O'Connor Reina et al., 2024 (16 minutes) and Rodríguez-Alcalá et al., 2022 (14 minutes)

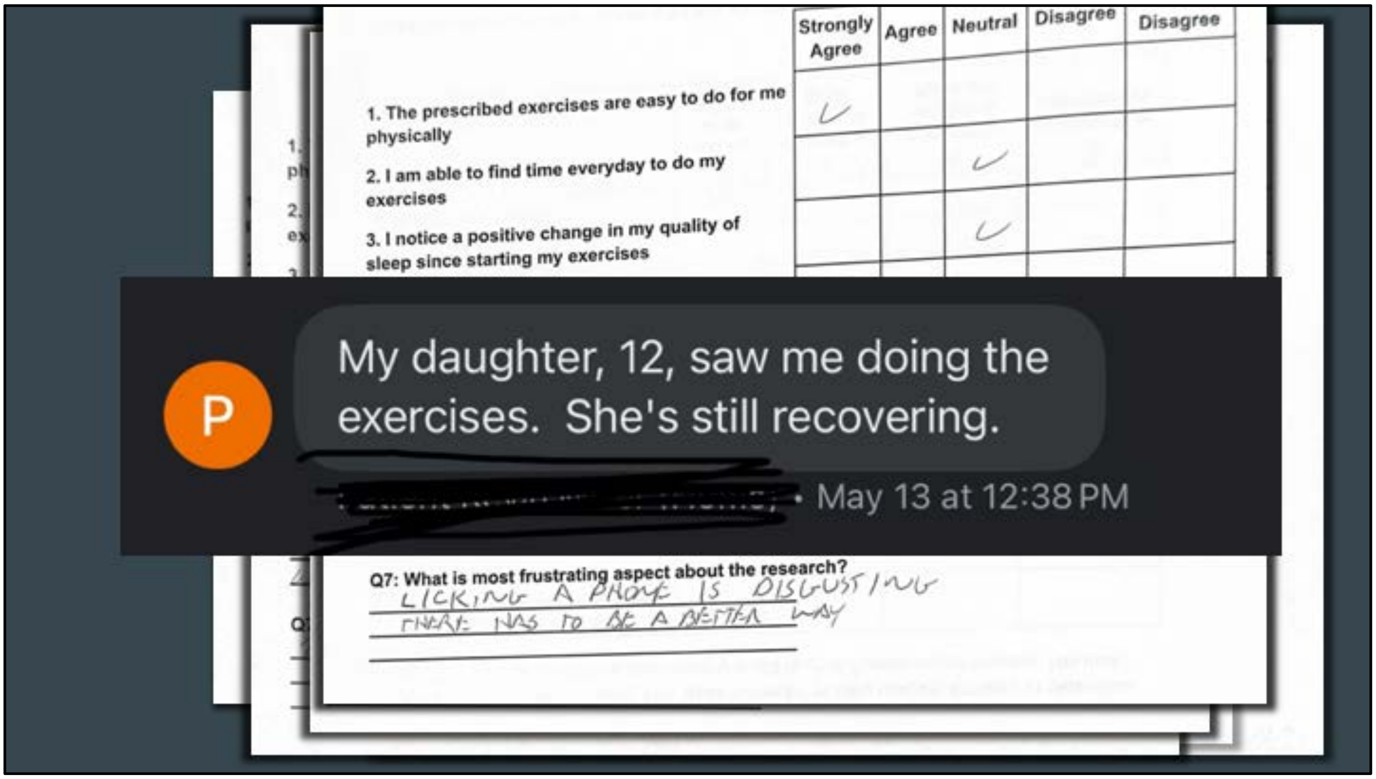
~ Confirms that **snore-time decreases are reproducible** across different delivery methods

~ MFT strengthens the **tongue base and oropharyngeal musculature**, improving airway tone and reducing tissue vibration during sleep

~ The observed reduction in snoring time corresponds with **objective AHI improvement** and **increased posterior IOPI strength** in our participants

~Both analog and app groups trended downward, supporting that the **exercise protocol itself,** rather than delivery format, displays improvement

~Aligns with Li et al. (2025) and O'Connor Reina (2024) findings that **enhanced airway muscle endurance shortens snoring duration** and improves perceived sleep quality


Strongly Agree
Agree
Neutral
Disagree
Disagree
1. The prescribed exercises are easy to do for me physically
2. I am able to find time everyday to do my exercises
3. I notice a positive change in my quality of sleep since starting my exercises
P
My daughter, 12, saw me doing the exercises. She's still recovering.
[redacted] • May 13 at 12:38 PM
Q7: What is most frustrating aspect about the research?
LICKING A PHONE IS DISGUSTING
THERE HAS TO BE A BETTER WAY

Limitations

~ OSA is multifactorial disease

~Unequal sizes in each group, unequal distribution of males vs. females

~ Duration of study

~ Compliance differences

~ Self reporting of analog patients

~ Use of wearable technology (Belun Ring)

~ Patients limited to CWRU Dental School and Cleveland sleep centers

~ Limited generalizability

~ Absence of long term follow up

CONCLUSION

- Both analog and app-based myofunctional therapy improved muscle tone and sleep parameters. Posterior tongue strength (IOPI) showed significant within-group improvement
- AHI, snore duration, Epworth, and sleep disturbance all decreased significantly when both groups were analyzed together
- Both analog and app-based myofunctional therapy improved muscle tone and sleep parameters. Posterior tongue strength (IOPI) showed significant within-group improvement
- AHI, snore duration, Epworth, and sleep disturbance all decreased significantly when both groups were analyzed together
- Analog group demonstrated higher compliance, likely influencing overall outcomes
- Belun Ring provided reliable, noninvasive data supporting the effectiveness of airway exercises
- Findings align with prior literature showing that strengthening orofacial muscles can improve airway function in OSA
- Results support myofunctional therapy as a feasible, accessible adjunctive treatment for mild to moderate OSA