Telemedicine-delivered myofunctional therapy remodels upper airway anatomy in obstructive sleep apnea: A prospective controlled study.

Short title: A nonrandomized study of telemedicine-delivered oropharyngeal exercises to treat OSA

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Declarations

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Informed Consent: Written informed consent was obtained from all participants prior to enrollment.

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Author Contributions:

- C.R.A. and C.O.R.: data analysis, manuscript drafting, critical revision.
- L.R.A.: screening, data collection and analysis, manuscript drafting.
- J.M.I.: critical revision.
- G.P. and P.B.: study conception, screening, bias assessment, drafting, critical revision.
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Study Objectives: To evaluate whether telemedicine-delivered myofunctional therapy (MT) results in measurable structural changes in the upper airway (UA) of patients with obstructive sleep apnea (OSA).

Methods: Prospective study of 60 adults with moderate-to-severe OSA randomly allocated to 3 treatment groups: moderate OSA + MT (n = 19), severe OSA + MT + continuous positive airway pressure (CPAP; n = 20), and OSA + CPAP but no MT (n = 18). MT comprised daily targeted oropharyngeal exercises for 3 months monitored with telemedicine . Pre- and postintervention assessments included sleep studies, submental ultrasound (interarterial distance, tongue thickness, and tongue volume), Iowa Oral Performance Instrument score, and DISE (VOTE classification).

Results: After 3 months, moderate OSA + MT subjects showed significant reductions in tongue volume (−8 cm^3; $P = .002$), tongue thickness (−4 mm; $P < .001$), and interarterial distance (−5 mm; $P < .001$). In severe OSA + MT + CPAP group, decreased tongue volume (−12 cm^3; $P < .001$) and interarterial distance (−7 mm; $P < .001$) emerged with no changes in tongue thickness. No significant changes occurred in controls. Absence of tongue collapse in DISE increased from 15% to 80% in moderate OSA + MT (P = .039) and from 15% to 55% in severe OSA + MT + CPAP (P = .109), with no changes in controls.

Conclusions: Telemedicine-based MT promotes measurable UA remodeling with submental ultrasound offering a practical, noninvasive monitoring tool. Thus, MT delivered via telemedicine may provide a scalable, patient-centered strategy to enhance structural outcomes and guide individualized OSA management.

Keywords: myofunctional therapy, obstructive sleep apnea, ultrasound, telemedicine, upper airway remodeling

BRIEF SUMMARY

This prospective study explored whether myofunctional therapy (MT), delivered through a telemedicine platform, could lead to measurable changes in the upper airway of patients with obstructive sleep apnea (OSA). Sixty adults were followed for three months with submental ultrasound and drug-induced sleep endoscopy. Patients with moderate OSA who performed MT showed clear reductions in tongue size and airway width, while no significant changes occurred in CPAP-only controls. These results suggest that telemedicine-based MT can expand upper airway structures, particularly in moderate OSA, and may help guide individualized treatment strategies.

Current Knowledge/Study Rationale:

Myofunctional therapy has been reported to improve symptoms of OSA, but its structural effects on the upper airway and the role of telemedicine-based delivery remain poorly documented.

Study Impact:

This study provides evidence that MT can induce measurable airway remodeling, especially in moderate OSA. Submental ultrasound proved useful for monitoring these changes, supporting the use of telemedicine MT as a scalable, patient-centered approach to individualized OSA management.

INTRODUCTION

Obstructive sleep apnea (OSA) is a highly prevalent disorder associated with significant cardiovascular, metabolic, and neurocognitive morbidity.[1] Anatomical factors, particularly those involving the tongue and oropharyngeal soft tissues, play a central role in upper airway (UA) collapsibility.[2] Recent imaging studies have shown that increased tongue volume, often due to fatty infiltration, is independently associated with OSA severity and may represent a modifiable therapeutic target.[3,4]

Myofunctional therapy (MT), a structured program of oropharyngeal exercises, may improve muscle strength[5,6] and reduce OSA severity in some patients.[7] However, whether MT is accompanied by measurable structural remodeling of the UA remains controversial[8-10]. Critics of MT efficacy argue that the UA dilator muscles, particularly those targeted by MT, lose neuromotor inputs during sleep, when airway collapse actually occurs, and thereby question the clinical utility of daytime oropharyngeal muscle training.[11,12] Furthermore, even though substantial changes are detectable in the upper airway of patients with OSA [13-15], expert consensus reports denote the lack of objective evidence linking MT to sustained anatomical changes.[11]

Current treatments, such as continuous positive airway pressure (CPAP), effectively splint the airway open during sleep but it remains unclear whether CPAP therapy induces long-term anatomical change.[16] Submental ultrasound has emerged as a practical, noninvasive tool for quantifying tongue volume, thickness, and the interarterial distance between the lingual arteries.[17-20] Compared with magnetic resonance imaging,[21] ultrasound is more portable, repeatable, and suitable for serial measurements, which makes it an attractive option for tracking potential anatomical changes during MT.[21]

Drug-induced sleep endoscopy (DISE) provides a complementary dynamic assessment of airway collapse patterns and allows investigation of the relationships between structural measurements and functional improvements.[22-25] To our knowledge, no prospective study has combined submental ultrasound and DISE to evaluate the anatomical and functional changes in patients undergoing MT, particularly when clinical management is delivered via a telemedicine-based platform.

To address some of these issues, the current study examined whether telemedicine-delivered MT could promote measurable structural changes in the tongue and UA, as assessed by submental ultrasound and DISE, in patients with moderate-to-severe OSA while comparing these changes with a control group of patients receiving CPAP without MT.

MATERIALS AND METHODS

Study design and registration

We conducted a prospective, nonrandomized clinical study to evaluate the effects of telemedicine-delivered MT on UA anatomy in patients with OSA. The study protocol was registered prospectively at ISRCTN (ISRCTN92645461) and has been previously published.[21] Ethical approval was obtained from the Provincial Research Ethics Committee of Málaga, Spain (AWGAP-2023-2). All participants provided written informed consent before enrollment.

Participants

Sixty adults aged 18–75 years with a diagnosis of moderate-to-severe OSA, confirmed by overnight polygraphy according to American Academy of Sleep Medicine criteria, were recruited consecutively between April 2023 and May 2025 from the Sleep Disorders Clinics at Hospital Quirónsalud Marbella (Marbella, Malaga) and Hospital Quirónsalud Campo de Gibraltar. (Palmones, Cadiz) Spain.

Inclusion criteria

- Age 18–75 years.

- Diagnosis of moderate or severe OSA (apnea–hypopnea index (AHI) ≥15 events/h).
- For CPAP users: stable use ≥4 h/night on ≥70% of nights.
- Body mass index (BMI) <30 kg/m².
- Ability to follow the protocol and provide informed consent.

Exclusion criteria

- Previous oropharyngeal surgery affecting the tongue or airway anatomy.
- Neurological or muscular disorders affecting swallowing or speech.
- Severe cardiovascular instability.
- Active neoplastic disease.
- Previous or ongoing oropharyngeal muscle rehabilitation or oral appliance therapy.
- Temporomandibular joint (TMJ) dysfunction or severe ankyloglossia.
- Inability to use a smartphone or access telemedicine tools.
- Weight variation >5 kg during the study period.

All anatomical evaluations were conducted by an otolaryngologist who was blinded to the subject group assignment to minimize assessment bias and to allow the isolation of MT-related effects.

Interventions

Study groups

Participants were allocated into three groups as follows.

- Moderate OSA + MT group: moderate OSA (AHI 15–30 events/h) treated exclusively with MT for 3 months.
- Severe OSA + MT + CPAP group: severe OSA (AHI >30 events/h) receiving stable CPAP plus MT.

- Control group (CPAP only): moderate-to-severe OSA with stable and adherent use of CPAP ≥3 months before enrollment but no MT.

Sample size justification

The sample size was calculated to detect a clinically relevant difference in UA anatomy (primary outcome: retrolingual diameter and area measured by submental ultrasound) between the MT and control groups using an analysis of covariance model in which the posttreatment values were adjusted for the baseline with a two-sided α of 0.05 and 80% power. Based on pilot data (effect size ≈ .5, correlation between baseline and postintervention values r ≈ .60) 18 participants per group were required. Allowing for a 10–15% dropout rate, the final target was 60 participants (i.e., 20 subjects per group).

Myofunctional therapy

MT comprised a standardized set of isotonic and isometric oropharyngeal exercises targeting the tongue, soft palate, and pharyngeal walls that aims to strengthen UA muscles and improve nasal breathing. The patients performed MT by interacting with a plug-in from a smartphone screen.[23] The AirwayGym® app provides a series of daily exercises that include both isometric (tension) and isotonic (concentration) exercises that are designed to be performed conveniently in any setting. It offers the additional advantage of providing prompt feedback that allows patients to see their progress and resolve problems with the help of a therapist. Before each exercise, an animated demonstration and video provide instructions for performing the exercise. After each exercise, patients receive visual, acoustic, and tactile feedback as a score on the success of their performance. A chat function is available through which patients can contact the therapist directly. This app complies with regulations 2002/58/EC and (EU) 2016/679 regarding data protection.

Exercises were performed for 20 minutes/day, 5–7 days/week, for 3 months, following instructional videos and supervised via the AirwayGym® telemedicine platform, which has been previously validated for OSA treatment.[23,26-33,23-30] Weekly online reviews ensured correct execution and adherence (Figure 1 panel a).

Assessments

Evaluations were conducted at baseline and at 3 months by the same team of blinded examiners.

Otorhinolaryngological examination

A complete otorhinolaryngological assessment was performed at baseline and at 3 months follow-up, and included anterior rhinoscopy, oropharyngeal inspection, and flexible nasopharyngolaryngoscopy. Tonsil size and tongue position were graded according to the Friedman staging[34] , and nasal patency was assessed for septal deviation and turbinate hypertrophy. The presence of oral breathing, pathological lingual frenulum, TMJ dysfunction, or other structural abnormalities that could influence UA collapsibility was recorded. Neck circumference and craniofacial features were also noted. All examinations were conducted by board-certified otolaryngologists blinded to the treatment allocation.

Submental ultrasound measures

The submental ultrasound technique is a noninvasive imaging method used to assess anatomical features of the tongue and adjacent vascular structures. It is particularly useful for evaluating the tongue volume (expressed as cm^3; Figure 1 panel b), tongue thickness (mm; Figure 1 panel c), and the position of and distance between the lingual arteries (Figure 1 panel d. The patient was placed in a supine position with the head extended slightly backward to provide optimal access to the submental region. The mouth remained closed, and the tongue was in a natural resting position. Submental ultrasound examinations were performed using the SonoSite 180 Plus system (SonoSite Inc., Bothell, WA, USA) with a linear L38/10–5 MHz transducer. The same machine was used for all measurements throughout the study to ensure consistency. A high-frequency linear array transducer (typically 7–15 MHz) was used in the coronal and sagittal submental approaches.[21] Gel was applied to the submental area to ensure good acoustic coupling. The transducer was positioned transversely under the chin (in the submental region), perpendicular to the sagittal plane, and then rotated or angled as necessary to obtain optimal images of the tongue.

Visualization of lingual arteries

Using color Doppler mode, the bilateral lingual arteries were identified in their course through the tongue. The interarterial distance (distance between the left and right lingual arteries) was measured at the level of their maximal visibility, typically near the midportion of the tongue.

Tongue thickness measurement

In B-mode, the vertical distance from the superior surface (tongue dorsum) to the inferior surface (tongue base) was measured at the midline or at a standardized lateral point.

Tongue volume estimation

Multiple cross-sectional images were acquired along the anterior–posterior axis of the tongue. The height, width, and thickness of the tongue were taken into account in different measurements to estimate the volume of the tongue using the ultrasound software to estimate the area. Tongue volume was estimated using geometric models or three-dimensional ultrasound, if available.

Tongue strength measurement

Iowa Oral Performance Instrument (IOPI) is used to measure the maximum pressure and resistance of the genioglossus muscle[35]. The IOPI is a validated device that measures tongue and lip strength by recording the maximum pressure exerted against an air-filled bulb. It provides objective, reproducible data about orofacial muscle performance that are helpful for monitoring functional changes during therapy.[36,37]

Sleep study

Overnigt polygraphy was performed for each participant using a type III sleep study device (SOMNOtouch™, SOMNOmedics GmbH, Randersacker, Germany). During polygraphy, the following parameters were evaluated for this study: mean oxygen saturation and lowest oxygen saturation, time of sleep spent with blood oxygen saturation <90%, and the AHI. The AHI was defined as the total number of apnea and hypopnea events per hour of sleep recorded in an overnight sleep study. Apnea was defined as ≥90% decrease in airflow for at least 10 s and hypopnea as a reduction in respiratory signals for ≥10 s associated with a minimum of 3% oxygen desaturation.[38]

Drug-induced sleep endoscopy

DISE was used with a standardized protocol involving target-controlled propofol infusion and video recording. The velum, oropharynx, tongue base, and epiglottis (VOTE) classification was performed by two independent blinded otolaryngologists, and their interrater agreement was assessed by calculating Cohen's kappa. [39,40]

Adherence monitoring

MT adherence was logged automatically by the AirwayGym® platform, which recorded the number and duration of sessions. Adherence was deemed satisfactory if ≥80% of the prescribed sessions were completed.

Endpoints

The primary endpoint was the change in tongue volume (cm^3) from the baseline to 3 months. Secondary endpoints included the changes in tongue thickness, lingual artery distance, and DISE tongue base collapse classification.

Statistical analysis

Statistical analyses were performed by the Department of Statistics at the University of Málaga, Spain, using IBM SPSS Statistics (v. 31; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median (interquartile range), and the distribution was assessed using the Kolmogorov–Smirnov test. Between-group differences were analyzed using analysis of variance or the Kruskal–Wallis test. Within-group changes were analyzed using the paired *t* test or Wilcoxon signed-rank test. Categorical variables were compared using chi-square or Fisher's exact test. Significance was set at $P < .05$.

RESULTS

Participants and follow-up

Sixty adults with moderate-to-severe OSA were enrolled and allocated to three groups: moderate OSA treated with MT only (n = 20), severe OSA treated with MT plus CPAP (n = 20), and a control group on stable CPAP not using MT (n = 20). Three participants did not complete the 3-month follow-up: one in the moderate OSA + MT group withdrew due to weight change >5 kg during the study; one control participant relocated; and another control participant developed temporomandibular joint dysfunction. No losses occurred in the severe OSA + MT + CPAP group. Thus, the final cohort completing the protocol comprised 19 participants in the moderate OSA + MT group, 20 subjects in the severe OSA + MT + CPAP group, and 18 controls (Figure 2).

Baseline characteristics

Baseline characteristics are presented in Table 1. Participants were predominantly middle-aged men with a BMI <30 kg/m^2. The sex distribution did not differ significantly between groups ($P = .235$). As expected, the Friedman tonsil and tongue position grades showed significant between-group differences (both *P* < .001); the severe OSA + MT + CPAP group had a higher percentage of patients with a grade 3 classification.

Baseline BMI (*P* = .78) and neck circumference (*P* = .82) did not differ significantly between groups, but baseline IOPI scores differed significantly between groups (*P* < .001): lip pressure was highest in the controls (23.6 ± 4.38 kPa), intermediate in the moderate OSA + MT group (20.4 ± 4.5 kPa), and lowest in the severe OSA + MT + CPAP group (16.05 ± 4.98 kPa. Tongue pressure followed a similar pattern (*P* < .001) and was lowest in the severe OSA + MT + CPAP group (35.5 ± 10.68 kPa) compared with the moderate OSA + MT (44.35 ± 9.5 kPa) and control (54.75 ± 7.93 kPa) groups.

As per study design, AHI was significantly higher in the severe OSA + MT + CPAP group (38.85 ± 5.98 events/h) than in the other two groups (both 22.6 ± 3.61 events/h) (*P* < .001).

Changes in submental ultrasound parameters (Figure 3)

After 3 months, the moderate OSA + MT group showed significant reductions in tongue volume, tongue thickness, and interarterial distance compared with baseline, while the severe OSA + MT + CPAP group showed reductions in tongue volume and interarterial distance but no significant change in tongue thickness. No significant changes emerged in the control group (Table 2) .Between-group analyses confirmed greater improvements in both MT intervention groups than in controls for tongue volume and interarterial distance (all *P* < .01).

Changes in DISE

DISE video recordings at baseline and at follow-up were reviewed independently by two board-certified otolaryngologists who were unaware of the treatment group allocation and clinical data. Their interrater agreement for VOTE scoring (κ = .82) was substantial.

In the moderate OSA + MT group, the percentage of patients without tongue base collapse (T0) increased significantly from 15% at the baseline to 80% after the intervention (*P* = .039). In the severe OSA + MT + CPAP group, T0 increased from 15% to 55%, a change that approached but did not reach statistical significance (*P* = .109). No significant differences were observed in the control group (*P* = .20) (Table 3).

Changes in IOPI scores

After 3 months, both intervention groups showed significant improvements in tongue and lip strength assessed by the IOPI; no changes were observed in the controls (Table 4). In the moderate OSA + MT group, both tongue and lip pressures increased significantly after 3 months. Similar improvements were also observed in the severe OSA + MT + CPAP group, while no significant changes occurred in the controls (Table 4) .

Changes in the apnea–hypopnea index

At 3 months, both MT intervention groups exhibited significant reductions in the AHI compared to baseline, whereas no significant changes occurred in the control group (Table 5)

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DISCUSSION

This study provides, for the first time, objective evidence that telemedicine-delivered MT can induce measurable structural changes in the upper airway of patients with OSA. Submental ultrasound[17,19] revealed significant reductions in tongue volume , along with a decreased distance between the lingual arteries even after only 3 months of treatment. Interestingly, tongue thickness did not change significantly in the severe OSA group, whereas other ultrasound parameters improved. These anatomical changes were accompanied by measurable gains in tongue strength[28] and improvements in DISE parameters[23-25] as well as in the magnitude of respiratory disturbance during sleep, as illustrated by the AHI.

As previously documented in a separate study[28] , the AHI decreased significantly after 3 months of MT in both intervention groups; These findings suggest that MT can positively influence OSA severity beyond subjective symptom relief,[41] likely by improving oropharyngeal muscle tone and reducing UA collapsibility. In contrast, no significant changes in the AHI were observed in the control group, which suggests that the effect of the AHI was attributable to the MT intervention rather than spontaneous night-to-night variability or CPAP alone[42]. Previous studies of MT have primarily focused on functional outcomes, such as reduction in the AHI[40] or improvements in daytime symptoms,[43] without objectively demonstrating anatomical remodeling. Current findings fill this important gap and confirm that targeted oropharyngeal exercises can modify both the function and anatomical substrate that contributes to UA collapse.

The clinical implications of these results are potentially far reaching. Our finding that MT can alter UA anatomy supports its role as a viable adjunctive therapy for OSA, particularly in patients with moderate disease or those with poor CPAP adherence,[44] or although not tested here, when surgical intervention is not indicated. By addressing the structural factors that contribute to pharyngeal collapsibility, MT may improve airway stability during sleep and reduce the severity of respiratory disturbance.[45]

Skepticism about MT is often rooted in the belief that daytime training cannot reverse the nocturnal loss of dilator muscle tone.[8] While acknowledging the importance of UA neuromuscular function, critics have emphasized the lack of robust structural evidence to support the use of MT.[46] The present study addresses this criticism directly by providing reproducible imaging data that confirms the presence of structural remodeling following objectively assessed adherent MT therapy.

The telemedicine format of the intervention deserves comment as well. We believe that continued interactions between the patient and the treatment team are an essential factor in the success of this intervention program. Allowing patients to complete their daily exercises at home without an imposed rigid schedule reduced the barriers to adherence compared with traditional face-to-face programs.[47] Remote monitoring ensured that progress could be tracked, and prompt feedback was given if adherence declined.[48] Rather than replacing the therapeutic relationship, this approach appeared to strengthen it, as patients reported feeling more supported and clinicians were able to make timely adjustments to the exercise plan.[49]

In addition to ultrasound, we used objective functional measures, including the IOPI,[50] to quantify tongue strength. These tools provide reproducible data on neuromuscular performance and can also serve as indirect indicators of MT adherence. Measurable gains were observed only in patients who trained consistently.[51] In our previous work, improvements in these measures correlated with better clinical outcomes, thereby enabling a valuable complement to imaging for monitoring the effectiveness of MT.[52]

The mechanisms underlying the anatomical changes observed are likely to be multifactorial.[53] Repeated isotonic and isometric activation of the oropharyngeal muscles may increase the baseline muscle tone and promote hypertrophy of the targeted muscle fibers, particularly in the genioglossus and intrinsic tongue musculature. Improved neuromuscular coordination may also enhance the capacity to maintain airway patency during sleep.[54] Prior imaging studies have shown that targeted training and weight loss can reduce intramuscular fat infiltration within the tongue, which is strongly associated with airway collapsibility.[4,55] Although we did not measure fat content directly, the reductions in tongue volume and thickness observed here are consistent with such possible decrease in fat tissue infiltration in the tongue.

In our cohort, the severe OSA group exhibited a greater reduction in the AHI despite showing smaller changes in submental ultrasound measurements. In contradistinction, the moderate OSA group achieved more pronounced anatomical remodeling but a smaller decrease in the AHI. These differences may reflect distinct mechanisms for the response to MT according to the baseline disease severity. In moderate OSA, improvements could be primarily driven by structural remodeling of the UA and increased muscle tone, as evidenced by significant ultrasound changes and gains in the IOPI score. Conversely, functional adaptations in severe OSA, such as improved neuromuscular coordination, altered pharyngeal dilator recruitment, and reduced collapsibility during sleep as documented on DISE, may play a more important role, even when structural changes are less pronounced. These patterns underscore the multifactorial nature of the effects of MT and suggest that anatomical and functional endpoints should be considered jointly when evaluating MT therapy outcomes.

One participant discontinued MT because of the onset of TMJ discomfort, despite having undergone a negative TMJ evaluation before therapy initiation. Although preintervention screening can reduce this risk, this isolated incident highlights the potential for TMJ symptoms to emerge during therapy, possibly related to changes in oral posture and increased muscular activity. For this reason, ongoing monitoring of TMJ status is advisable throughout MT protocols, and collaboration with maxillofacial specialists should be considered when symptoms arise.

A methodological strength of this study is the complementary use of two independent assessment modalities. Although submental ultrasound provides a noninvasive and repeatable method to quantify tongue volume, thickness, and interarterial distance, it remains partially operator dependent and subject to measurement variability.[16] To mitigate this limitation, we incorporated DISE for the objective dynamic evaluation of UA collapse. All DISE procedures were recorded, anonymized, and reviewed blindly by two independent expert otolaryngologists, who achieved optimal interrater agreement.[53] This dual approach strengthens the validity of our anatomical findings and also ensures that the changes observed in airway structure are corroborated by real-time functional assessment during induced sleep, thereby reducing the potential bias associated with any single measurement technique. Of course, overnight polygraphy at the beginning and upon completion of the trial further reinforce the validity of the findings.

Limitations

One of the limitations of this study is the reliance on submental ultrasound for anatomical assessment because operator-dependent variability can affect reproducibility. We minimized this potential problem by using the same experienced examiner for all measurements and blinding the scorer to the group allocation. The inclusion of a control group of moderate-to-severe OSA patients on stable CPAP therapy who were assessed under identical conditions also helped to mitigate the potential for measurement bias. A second limitation is the nonrandomized study design, which leaves open the possibility of selection bias despite similar baseline characteristics among the three groups. A third limitation is that the follow-up period of 3 months does not allow us to draw conclusions about the long-term stability of the observed changes or to establish whether further improvements are possible. Thus, longer interventions may be advisable and future studies including discontinuation of MT and monitoring of the functional and structural changes over time seem necessary. The cohort included predominantly patients with a low average BMI (26.97 kg/m^2) and no morbidly obese patients were evaluated. Consequently, our findings may not be fully generalizable to patients with OSA and obesity, whose tongue fat content and airway collapsibility may substantially differ and therefore their responses to MT may not align with those reported herein. Finally, we did not quantify lingual fat content directly, which may have helped clarify whether fat reduction contributed to the decrease in tongue volume.

CONCLUSIONS

Telemedicine-delivered MT over a period of 3 months resulted in measurable UA remodeling in patients with OSA, as shown by the significant reductions in tongue volume and thickness, improved tongue strength, and favorable changes in tongue base collapse on DISE, particularly in those with moderate disease, as further illustrated by improvements in nocturnal respiratory disturbance. These findings provide objective structural and functional evidence that support MT as a noninvasive adjunctive treatment of non-obese or overweight OSA patients. Integrating ultrasound and DISE with functional measures enables comprehensive monitoring, and the telemedicine format enhances patient accessibility and adherence. Larger, long-term randomized trials are needed to confirm the durability and clinical impact of telemedicine-delivered MT.

ABBREVIATIONS

AHI, apnea–hypopnea index

BMI, body mass index

CI, confidence interval

CPAP, continuous positive airway pressure

DISE, drug-induced sleep endoscopy

IOPI, Iowa Oral Performance Instrument

MT, myofunctional therapy

OSA, obstructive sleep apnea

TMJ, temporomandibular joint

T0, percentage of patients without tongue base collapse

UA, upper airway

VOTE, velum, oropharynx, tongue base, and epiglottis

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Table 1—Baseline data.

Variable	Moderate OSA + MT (n = 19)	Severe OSA + MT + CPAP (n = 20)	Control (CPAP only) (n = 18)	*P* value
Demographics				
Age, years	51.35±14.07	51.05±10.78	40.94±10.86	.15
Male sex, n (%)	13 (68)	18 (90)	15 (83)	.235
Female sex, n (%)	6 (31)	2 (10)	3 (16)	.17
Anthropometrics				
BMI, kg/m²	27.66 ± 1.96	29.80 ± 3.50	23.09 ± 3.46	.78
Neck circumference, cm	39.71 ± 2.10	40.06 ± 2.23	36.77 ± 3.19	.82
Friedman staging				
Tonsil grade 1, n (%)	0 (0)	0 (0)	3 (15)	<.001
Tonsil grade 2, n (%)	11 (55)	0 (0)	6 (30)	<.001
Tonsil grade 3, n (%)	9 (45)	20 (100)	11 (55)	<.001
Tongue position grade 1, n (%)	0 (0)	0 (0)	2 (10)	<.001
Tongue position grade 2, n (%)	8 (40)	0 (0)	6 (30)	<.001
Tongue position grade 3, n (%)	12 (60)	20 (100)	12 (60)	<.001
Functional measures				
IOPI lips, kPa	20.4 ± 4.50	16.05 ± 4.98	23.6 ± 4.38	<.001
IOPI tongue, kPa	44.35 ± 9.0	35.5±10.68	54.75±7.93	<.001

Abbreviations: BMI = body mass index; CPAP = continuous positive airway pressure; IOPI = Iowa Oral Performance Instrument; MT = myofunctional therapy; OSA = obstructive sleep apnea.

Table 2—Changes in submental ultrasound parameters after 3 months.

Parameter	Group	Pre (mean ± SD)	Post (mean ± SD)	Δ (absolute)	% Change	95% CI for Δ	*P* value
Tongue volume, cm^3	Moderate OSA + MT (n = 19)	85 ± 5.31	77 ± 8.23	–8	–9%	−11.18 to −5	.002
	Severe OSA + MT + CPAP (n = 20)	93 ± 5.45	81 ± 8.45	–12	–13%	−15.10 to −8.90	<.001
	Control (CPAP only) (n = 18)	82.9±6.46	82.43±6.20	NS	—	—	NS
Tongue thickness, mm	Moderate OSA + MT (n = 19)	41 ± 3.48	37 ± 3.18	–4	–10%	−5.27 to −2.73	<.001
	Severe OSA + MT + CPAP (n = 20)	47 ± 3.55	46 ± 3.13	–1	–2%	−2.24 to 0.24	.08
	Control (CPAP only) (n = 18)	40.27±5.65	40.28±4.93	NS	—	—	NS
Interarterial distance, mm	Moderate OSA + MT (n = 19)	31 ± 4.05	26 ± 4.05	–5	–16%	−6.27 to −3.73	<.001
	Severe OSA + MT + CPAP (n = 20)	36 ± 4.06	29 ± 4.02	–7	–19%	−8.24 to −5.76	<.001
	Control (CPAP only) (n = 18)	32.26±3.84	32.1±3.80	NS	—	—	NS

Notes: Values are presented as mean ± standard deviation (SD) unless otherwise indicated. Δ = the absolute change from the baseline.
Abbreviations: BMI = body mass index; CI = confidence interval; CPAP = continuous positive airway pressure; MT = myofunctional therapy; NS = not significant; OSA = obstructive sleep apnea.

Table 3—Changes in VOTE classification for tongue base collapse on DISE.

Group	Baseline T0, n (%)	Baseline T1+T2, n (%)	Post T0, n (%)	Post T1/T2, n (%)	*P* value (McNemar)
Moderate OSA + MT (n = 19)	3 (15.8)	16 (84.2)	15 (78.9)	4 (21.1)	.039
Severe OSA + MT + CPAP (n = 20)	3 (15.0)	17 (85.0)	11 (55.0)	9 (45.0)	.109
Control (CPAP only) (n = 18)	4 (22.2)	14 (77.8)	5 (27.8)	13 (72.2)	.200

Abbreviations: T0 = no tongue base collapse; T1/T2 = partial or complete collapse; CPAP = continuous positive airway pressure; DISE = drug-induced sleep endoscopy; MT = myofunctional therapy; OSA = obstructive sleep apnea.

Table 4—Changes in IOPI measurements after 3 months.

Parameter	**Group**	**Pre (mean ± SD)**	**Post (mean ± SD)**	**Δ (absolute)**	**95% CI for Δ**	***P* value**
Tongue pressure, kPa	Moderate OSA + MT (n = 19)	44.35 ± 9.50	54.98 ± 1.57	+10.63	5.72 to 15.53	.002
	Severe OSA + MT + CPAP (n = 20)	35.5 ± 10.68	50.42 ± 1.64	+14.92	9.93 to 19.91	<.001
	Control (CPAP only) (n = 18)	53.77 ± 7.93	54.16 ± 7.95	NS	–0.84 to 0.066	.08
Lip pressure, kPa	Moderate OSA + MT (n = 19)	20.4 ± 4.50	33.08 ± 1.34	+12.68	10.57 to 14.79	<.001
	Severe OSA + MT + CPAP (n = 20)	16.05 ± 4.98	31.29 ± 5.91	+15.24	12.58 to 17.89	<.001
	Control (CPAP only) (n = 18)	23.36 ± 4.38	23.74 ± 4.72	NS	–1.15 to 0.42	.30

Notes: Values are presented as mean ± standard deviation (SD) unless otherwise indicated. Δ = the absolute change from the baseline.
Abbreviations: CI = confidence interval; CPAP = continuous positive airway pressure; IOPI = Iowa Oral Performance Instrument; MT = myofunctional therapy; NS = not significant; OSA = obstructive sleep apnea.

Table 5—Changes in apnea–hypopnea index (AHI) after 3 months.

Group	**Pre (mean ± SD)**	**Post (mean ± SD)**	**Δ (absolute)**	**95% CI for Δ**	***P* value**
Moderate OSA + MT (n = 19)	22.8 ± 3.61	16.02 ± 4.53	−6.78	−9.50 to −4.11	.002
Severe OSA + MT + CPAP (n = 20)	40.9 ± 5.98	29.81 ± 9.51	−11.09	−16.75 to −5.42	.0016
Control (CPAP only) (n = 18)	22.6 ± 3.61	20.65 ± 3.32	NS	−4.53 to 0.42	.071

Note: Values are presented as mean ± standard deviation (SD) unless otherwise indicated. Δ = the absolute change from the baseline

Abbreviations: AHI = apnea–hypopnea index; CI = confidence interval; CPAP = continuous positive airway pressure; MT = myofunctional therapy; NS = not significant; SD, standard deviation; OSA = obstructive sleep apnea.