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Title:

Myofunctional Therapy to Treat Obstructive Sleep Apnea: A Systematic Review and Meta-Analysis

Short running title: Myofunctional therapy for OSA

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Abstract

Objective

To systematically review the literature for articles evaluating myofunctional therapy (MT) as treatment for obstructive sleep apnea (OSA) in children and adults and to perform a meta-analysis on the polysomnographic (PSG), snoring and sleepiness data.

Data Sources

Web of Science, Scopus, MEDLINE and The Cochrane Library.

Review Methods

The searches were performed through June 18, 2014. The PRISMA statement was followed.

Results

Nine adult studies (120 patients) reported polysomnography, snoring and/or sleepiness outcomes. The pre and post-MT apnea-hypopnea indices (AHI) decreased from a mean ± standard deviation (M±SD) of 24.5±14.3/h to 12.3±11.8/h, mean difference (MD) -14.26 [95% CI -20.98, -7.54], p-value <0.0001. Lowest oxygen saturations improved from 83.9±6.0% to 86.6±7.3%, MD 4.19 [95% CI 1.85, 6.54], p-value =0.0005. Polysomnography snoring decreased from 14.05±4.89% to 3.87±4.12% of total sleep time, p-value <0.001, and snoring decreased in all three studies reporting subjective outcomes. Epworth sleepiness scale decreased from 14.8±3.5 to 8.2±4.1. Two pediatric studies (25 patients) reported outcomes. In the first study of 14 patients, the AHI decreased from 4.87±3.0/h to 1.84±3.2/h, p-value =0.004. The second study evaluated children who were cured of OSA after adenotonsillectomy and palatal expansion, and found that 11 patients who continued MT remained cured (AHI 0.5±0.4/h), while 13 controls had recurrent OSA (AHI 5.3±1.5/h) after 4 years.

Conclusion

Current literature demonstrate that myofunctional therapy decreases AHI by approximately 50% in adults and 62% in children. Lowest oxygen saturations, snoring and sleepiness outcomes improve in adults. Myofunctional therapy could serve as an adjunct to other OSA treatments.

Key Words

Exercise Therapy/methods*, Myofunctional therapy/methods*, obstructive sleep apnea, sleep apnea syndromes

Introduction

Several medical and surgical treatment modalities exist as treatment for obstructive sleep apnea (OSA)[1-3]. Four pathophysiological traits seen in OSA patients include: the passive critical closing pressure of the upper airway (Pcrit), arousal threshold, loop gain and muscle responsiveness (PALM) with categories of 1, 2, 2a, 2b and 3[4]. It has been demonstrated that patients in 4 out of 5 PALM categories will benefit from anatomic interventions[4]. Because the dilator muscles of the upper airway play a critical role in maintaining an open airway during sleep, researchers have explored exercises and other airway training (singing, didgeridoo, instrument playing) that target oral cavity and oropharyngeal structures as a method to treat OSA[5-7]. Myofunctional therapy and proper tongue positioning in the oral cavity has been described since 1918 to improve mandibular growth, nasal breathing and facial appearance[8]. Guimaraes has proposed myofunctional therapy as a treatment for OSA since the 1990s[9]. Myofunctional therapy is comprised of isotonic and isometric exercises which target oral (lip, tongue) and oropharyngeal structures (soft palate, lateral pharyngeal wall)[7,10]. There have been an increasing number of studies evaluating the effect of myofunctional therapy in the form of case studies, case series and most recently two randomized-controlled trials[7,10-13].

The most comprehensive myofunctional therapy exercises are described by Guimaraes et al. and involve the soft palate, tongue, facial muscles and address stomatognathic functions[7]. For soft palate exercises, patients pronounce oral vowel sounds either continuously (isometric exercises) or intermittently (isotonic exercises)[7]. Tongue exercises include moving the tongue along the superior and lateral surfaces of the teeth, positioning the tongue tip against the anterior aspect of the hard palate, pressing the entire tongue against the hard and soft palate and forcing the tongue onto the floor of the mouth[7]. Facial exercises address the lip (i.e., contraction and relaxation of the orbicularis oris), buccinators (i.e., suction movements and application of intraoral finger pressure against the buccinator muscles) and jaw muscles (i.e., lateral jaw movements)[7]. Additionally, stomatognathic functions are addressed by instructing patients to inhale nasally and exhale orally without and then with balloon inflation, and performing specific swallowing and chewing exercises (i.e., swallowing with the teeth clenched together, tongue positioned in the palate and without contraction of perioral muscles; alternating chewing sides)[7]. A newer study describes a device that conditions and strengthens oral and tongue muscles[12].

The objective of this study is to systematically review the literature for articles evaluating myofunctional therapy or oral/oropharyngeal exercises as treatment for obstructive sleep apnea in both children and adults and to perform a meta-analysis on the available polysomnographic and sleepiness data.

Methods

Search Strategy

A search was performed on Web of Science, Scopus, MEDLINE and The Cochrane Library, initially January 18, 2014, with an update on June 18, 2014. MeSH terms and keywords used for the search included various combinations of the following: “myofascial reeducation,”

“myofunctional therapy,” “obstructive sleep apnea,” “orofacial myotherapy,” “oral myotherapy,” “oropharyngeal exercises,” “sleep,” “sleep apnea syndromes,” “speech therapy,” “upper airway exercises,” and “upper airway remodeling.” One example of a MEDLINE search is: ((("Myofunctional Therapy"[MeSH]) AND "Sleep Apnea Syndromes"[MeSH])) OR (“sleep” AND (“myofascial reeducation” OR “myofunctional therapy” OR “orofacial myotherapy” OR “oral myotherapy” OR “oropharyngeal exercises” OR “speech therapy” OR “upper airway exercises” OR “upper airway remodeling”)).

For each of the searches, the titles and abstracts were screened and the full text versions of articles that met criteria were downloaded. Full texts were reviewed and any referenced articles that were not already obtained were ordered and obtained. “Related citations” were also reviewed during the searches, and the “cited by” function on Google Scholar was also used to identify any additional studies.

Study selection

Criteria for inclusion included peer-reviewed studies (published articles or abstracts) evaluating oral or oropharyngeal myofunctional therapy as an isolated treatment for either adult or pediatric obstructive sleep apnea; studies needed to report quantitative polysomnographic, snoring and/or sleepiness data pre and post-treatment or they needed to report the percentage of difference between pre and post-treatment outcomes. All languages were included. Exclusion criteria included studies evaluating singing, instrument playing, and studies without quantitative data. If individual patient data was reported and patients lost 10% or more of their body weight, then those patients were excluded. Studies in which the myofunctional therapy patients also underwent additional interventions such as continuous positive airway pressure (CPAP) therapy, mandibular advancement device therapy, sleep apnea surgery, allergy management, weight loss management, or any other intervention which could also contribute to improved sleep apnea outcomes were excluded (unless the additional interventions were performed in

control groups and the data was provided separately for both myofunctional therapy and control groups).

Data abstraction and Study Quality Assessment

Authors MC, JA and SZ independently performed a search of the literature and screened titles, abstracts and downloaded the articles for inclusion. The decision to include the articles was made by consensus, and if necessary the final decision was made by author MC. Data collected included patient ages, body mass indices (BMIs), polysomnographic data (apnea-hypopnea indices (AHIs), lowest oxygen saturation), snoring and sleepiness data. If data were missing from the articles, then the corresponding author was contacted in an attempt to obtain the data. The corresponding author of Suzuki et al. was contacted and confirmed that the reported oxygen saturation data was for lowest oxygen saturation and that tongue training was involved as part of the myofunctional therapy device training[12].

The National Institute for Health and Clinical Excellence (NICE) quality assessment tool was used to evaluate the quality of the included studies. The instrument consists of 8 items which are assessed for each individual study.

Statistical Analysis

The statistics were performed with the Statistical Package for Social Sciences software (SPSS) version 20.0. Means and standard deviations were calculated pre and post myofunctional therapy. Studies providing raw patient data without means and standard deviations were manually input into SPSS for calculation; or if individual scatter plots with pre and post-treatment data were available, the estimated data point values were used to calculate the means and standard deviations. The null hypothesis for this study is that there is no difference in outcome data pre and post-myofunctional therapy. For combining data, a two-tailed, paired t-test was performed (a p-value <0.05 was the cutoff for significance). The Cochrane Collaboration's Review Manager (REVMAN) Software version 5.3 was used for meta-

analysis. A random effects model was used if moderate or high levels of heterogeneity existed or a fixed effects model was used if no or low levels of heterogeneity existed. When pooling the data in studies, the means, standard deviations and 95% confidence intervals (CI) were calculated by REVMAN. Heterogeneity was assessed by I^2 statistic (inconsistency levels: low = 25%, moderate = 50% and high = 75%)[14] and the Cochran Q statistic (with significant heterogeneity being considered when a p-value of ≤0.1 was obtained)[15]. If heterogeneity existed, then a sensitivity analysis was performed by removing each of the studies individually to identify the source(s).

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were downloaded and were adhered to during this review[16].

Results

A total of 226 studies were screened for relevance, and 204 were excluded. After identification of 22 potentially relevant studies, they were downloaded and the reviews of the reference lists yielded an additional 6 studies, for a total of 28 studies[7-13,17-36]. Nine were review articles, [8,20,22,27,30,32-34,36] two reported no intervention,[24,31] two studied lip exercises and the effect on lip thickness,[21,37] one reported breathing exercises not involving oral cavity or oropharyngeal structures,[28] one was a letter to the editor[11] and two studies were abstracts in which data was later reported in the authors' journal articles[19,25]. Eleven studies met criteria and were included in this review. Individual patient data was reported by one pediatric study[35] and one adult study[12], while the remaining nine studies reported outcomes with means and standard deviations[7,9,10,13,17,18,23,26,29]. Figure 1 summarizes the flow for study selection.

Methodological quality of the included studies

The studies included in this review included one abstract,[26] one retrospective case report,[23] three retrospective case series,[9,10,18] three prospective case series,[12,17,29] one randomized trial,[35] and two randomized controlled trials[7,13]. Most of the studies satisfied 4 to 6 out of the 8 NICE quality assessment tool items (presented in Table S1 of supplemental

material). The main limitations were that the total number of patients in most studies was low, the studies were at single institutions (except one which was multi-centered) and most studies did not explicitly stated that patients were consecutive.

Adult Studies

A total of 9 adult studies (120 patients, age 44.5±11.6 years, BMI 28.9±6.2 kg/m^2) reported polysomnography and/or sleepiness outcomes (Table 1). Baz et al. reported using AASM scoring criteria but did not specify which year[17], Diaferia et al. and Guimaraes et al. reported using 1999 AASM scoring criteria[7,13], Suzuki et al. scored based on the 2005 update to AASM scoring criteria, and the remaining 5 studies did not specify which polysomnography scoring criteria were used[9,18,23,26,29].

The pre and post-MT AHI decreased from a M±SD (82 patients) from 24.5±14.3/h to 12.3±11.8/h, with a mean difference (MD) of -14.26 [95% CI -20.98, -7.54], Z score of 4.16 (p-value < 0.0001) (Figure 2). Both the I^2 statistic (91%) and the Q statistic (value of <0.00001) demonstrated significant heterogeneity, therefore, studies were individually excluded to identify the source(s). Exclusion of the studies by Suzuki et al. and Berreto et al. resulted in no heterogeneity in the remaining 73 patients, with the I^2 statistic = 0% and the Q statistic value of 0.6. The mean difference for the remaining studies was -10.49 26 [95% Confidence Interval (CI) -12.67, -8.31]. In adult studies in which myofunctional therapy was performed for at least 3 months, the mean AHI reduced from 25.2±14.6/h to 12.6±12.2/h, which is a 50% reduction.

The lowest oxygen saturation improved in 82 patients from 83.9±6.0% to 86.6±7.3%, MD of 4.19 [95% CI 1.85, 6.54], with an overall Z score of 3.5 (p = 0.0005), see Figure 3. Both the I^2 statistic (59%) and the Q statistic (value of 0.05) demonstrated significant heterogeneity, therefore, studies were individually excluded to identify the source(s). Exclusion of Suzuki et als' study and Berreto et als' study resulted in no heterogeneity in the remaining 73 patients,

with the I^2 statistic = 0% and the Q statistic value of 0.56. Oxygen desaturation index was reported by one study, and demonstrated a reduction from 14.53±5.04 to 9.27±4.27, pre and post-MT, respectively[17]. Sleepiness decreased in all studies reporting the outcome. The Epworth Sleepiness Scale[38] decreased in 75 patients from 14.8±3.5 to 8.2±4.1, MD of -6.81 [95% CI -7.79, -5.82], with an overall Z score of 13.55 ($p < 0.00001$), see Figure 4. Both the I^2 statistic (0%) and the Q statistic (value of 0.8) demonstrated no heterogeneity.

Snoring

Snoring changes were evaluated by 4 studies, Baz et al.,[17] Berreto et al.[18], de Paula Silva et al.[23] and Guimaraes et al.,[7] see Table 2. Baz et al. reported that 30 patients snored before therapy and 16 snored after therapy, p-value 0.008 (yes vs. no, article did not specify if patient or bedpartner was asked) and the polysomnography demonstrated that the percent of total sleep time spent snoring decreased from 14.05±4.89% to 3.87±4.12% (before and after, respectively), p-value<0.001[17]. Guimaraes et al. found snoring frequency decreased by 25% (article did not specify if patient or bedpartner was asked) from 4 to 3 (based on 0 = never to 4 = everyday), p-value 0.001, and the snoring intensity decreased by 66% from 3 to 1 (based on 1 = similar to breathing and 3 = very loud) with a p-value of 0.001; whereas the control groups had no change in snoring frequency or intensity[7]. The case study by de Paula Silva et al. demonstrated a decrease in snoring intensity after 8 sessions[23]. Berreto et al. described 2 patients who decreased from a (bedpartner) snoring score of 3 down to 2 (0 = snoring absence, 1 = heavy breathing, 2 = light snoring, 3 = snoring that disturbs the bed partner and 4 = snoring that can be heard outside the bedroom)[18].

Pediatric Studies

A total of 2 pediatric studies (25 patients, age 8.4±3.1 years) reported polysomnography and/or sleepiness outcomes. Both pediatric studies reported using 2007 American Academy of

Sleep Medicine (AASM) scoring criteria, and Guilleminault et al. also specified that hypopneas were scored with a 50% reduction in nasal cannula curve and an associated 3% or more reduction in oxygen saturation, while Villa et al. did not specify the hypopnea scoring criteria[10,35]. The study by Villa et al. was a prospective randomized-controlled trial, in which post-adenotonsillectomy patients were randomized to either oropharyngeal exercises or control group[35]. The treatment group in this study consisted of 14 patients and the pre and post-myofunctional therapy AHI was evaluated after 2 months of oropharyngeal exercises. The AHI mean ± standard deviation (M±SD) reduced from 4.87±3.0/h to 1.84±3.2/h, p-value 0.004 (a 62% reduction)[35]. The control group had minimal change in AHI during the 2 month period (4.56/h down to 4.11/h)[35]. The study by Guilleminault et al. was a retrospective chart review, evaluating 24 children who were cured by the combination of adenotonsillectomy and palatal expansion (AHI 0.4±0.3); and 11 of the children received myofunctional therapy (intervention group) and 13 children did not receive myofunctional therapy (controls)[10]. At the 4-year follow-up, the children who practiced myofunctional therapy in the long-term remained cured of OSA (AHI 0.5±0.4), compared to children who were never trained to perform the exercises and subsequently had a recurrence of OSA (AHI 5.3±1.5/h)[10]. Although both pediatric myofunctional therapy studies compared the intervention groups to control groups, neither study reported pre and post-treatment lowest oxygen saturation or sleepiness outcomes.

Discussion

This systematic review and meta-analysis of 9 adult and 2 pediatric studies evaluating the effect of myofunctional therapy on OSA has five main findings. First, myofunctional therapy provides a reduction in AHI of approximately 50% in adults and 62% in children. The pre- and post-MT AHI for adults decreased from 24.5±14.3/h to 12.3±11.8/h, mean difference (MD) of -14.26 [95% CI -20.98, -7.54] (p-value < 0.0001). For pediatric patients, the pre and post-MT M±SD for AHI decreased from 4.87±3.0/h to 1.84±3.2/h, p-value = 0.004. Additionally, the study

by Guilleminault et al. reported that 11 children remained cured of OSA (AHI of 0.5±0.4/h) after continuing MT for four years. There was heterogeneity, and the studies by Suzuki et al. and Berreto et al. were shown to be the sources. Suzuki et al. had 6 patients, who used an oral exercise device to help train, but the length of time between polysomnography was 2 months, whereas the remaining adult studies' reporting AHI had a follow-up duration of at least 3 months between polysomnography. Had the study been extended to 3 months, there may have been additional improvement in AHI. In studies with control groups, there was little to no improvement in the AHI for the control groups compared to improvement the MT intervention group. There is also a clear improvement in lowest oxygen saturation by approximately 3-4%, with the meta-analysis of 81 patients demonstrating a mean difference pre and post-MT of 4.19%, [95% CI 1.85, 6.54]. The oxygen desaturation index (ODI) was only reported by Baz et el, demonstrating a 36% reduction, but the article did not specify whether the ODI in the study was based on 3% or 4% desaturation[17].

Second, myofunctional therapy decreases snoring both subjectively and objectively. Four studies compared the pre and post-MT outcomes and it was noted that snoring decreased after therapy (3 of 4 studies quantified the snoring). The polysomnography demonstrated a 72.4% percent reduction in snoring pre- vs post-MT (14.05±4.89% to 3.87±4.12%, before and after, respectively), p-value<0.001[17]. With regard to subjective improvement in snoring intensity, the 3 studies quantifying the outcomes reported that post-treatment there was a decrease in snoring to either light snoring or the sound was similar to normal breathing.

Third, subjective sleepiness also improves post-myofunctional therapy as demonstrated by a clear reduction Epworth Sleepiness Scale for the 93 patients in which it was administered, with a reduction from 14.8±3.5 to 8.2±4.1 (in 75 patients in which M±SDs were reported)[7,13,17,18,26,29]. The post-treatment ESS is below the threshold for hypersomnia, which is generally considered to be 11 or higher on the scale[39]. Additionally, in the 1999 study by

Guimaraes, the article reported a subjective reduction in sleepiness, however, the use of a validated sleepiness scale was not specified[9].

Fourth, despite the heterogeneity in oral and oropharyngeal exercises, overall the improvements in polysomnographic outcomes and sleepiness were consistent. Myofunctional therapy was performed for as little as 5 minutes, twice daily, 4 days a week for 2 months[12] to as many as 10 minutes, 3-5 times daily for 3 months[17]. The longest published experience with myofunctional therapy for adult OSA has been Guimaraes which is 6 months[9]. Guimaraes has also published thorough instructions for performing the exercises which involve the soft palate, tongue, facial muscles and stomatognathic functions to be performed 30 minutes a day[7].

Lastly, future research is needed to help explain the pathophysiology and mechanism of action of myofunctional therapy as treatment for obstructive sleep apnea. It can be hypothesized that the exercises improve oral and/or oropharyngeal muscle tone and also may decrease the amount of fatty deposition of the tongue. It can be recommended that future researchers consider using the standardized exercises which have been developed and used over a period of several years by Guimaraes et al. as they have the most experience with the therapy[7]. As pointed out by Guimaraes et al., the fact that the myofunctional therapy is based on an integrative approach with several exercises, it is not possible to determine the effects of specific exercises to determine which ones contribute the most to improvement in outcomes[7]; therefore, future studies could consider exploring the effect of individual exercises. Individual patient data was not available for most studies, therefore, a sub-analysis could not be performed for BMI, AHI, age, etc. based on the current literature. However, with regard to BMI, Guimaraes et al.[7] and Baz et al.[17] had significant reductions in AHI in overweight (BMI M±SD 29.6±3.8) and obese patients (BMI M±SD 33.6±2.0). With regard to age, the myofunctional therapy has been shown effective in children and adults of all ages studied thus far, ranging from 3 to 60 years old.

Limitations

A total of 145 patients (including 25 children) were included in this meta-analysis; however, the magnitude of the effects were highly significant. Although there were nine adult studies, a significant limitation for pediatric studies is that currently only two articles have been published. Additionally, long-term follow-up for more than 6 months is limited. Except the study by Guilleminault et al., which followed patients for 4 years, all of the other studies spanned 2-6 months. The study by Guilleminault et al. demonstrates a long-term (4 years) maintenance of reduction in AHI and alleviation of OSA symptoms in patients who continued to perform myofunctional therapy exercises, compared to the control group that had recurrence of symptoms and recurrence of an elevated AHI at the 4-year follow-up[10]. Because this is the only study which has reported outcomes longer than 6 months after initiation of myofunctional therapy exercises, additional long-term studies are needed to demonstrate the lasting effects of continued myofunctional therapy. Questions that have not been addressed which could be studied in the future include whether there is a relationship with the tongue exercises and changes in the tongue and palatal muscle tone and/or strength, tongue size (tongue fat) and overall upper airway volume changes pre and post-treatment.

Conclusion

Current literature demonstrate that myofunctional therapy decreases AHI by approximately 50% in adults and 62% in children. Lowest oxygen saturation, snoring and sleepiness outcomes improve in adults. Myofunctional therapy could serve as an adjunct to other OSA treatments.

Disclaimer

The views herein are the private views of the authors and do not reflect the official views of the Department of the Army or the Department of Defense.

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Table S1. General characteristics of included patients and quality criteria of included studies. AI = apnea index; AHI = apnea-hypopnea index; ESS = Epworth Sleepiness Scale; mos = months; N = number of patients with intervention, NA = Not applicable; N.R. = Not reported; O2 sat = oxygen saturation; PCS = prospective case series; RCR = retrospective case report, RCS = retrospective case series; RCT = randomized controlled trial; RT = randomized trial; yrs = years; *Quality Assessment of cases series studies checklist from National Institute for Health and Clinical Excellence (NICE): 1) Case series collected in more than one center, i.e. multi-center study? 2) Is the hypothesis/aim/objective of the study clearly described? 3) Are the inclusion and exclusion criteria (case definition) clearly reported? 4) Is there a clear definition of the outcomes reported? 5) Were data collected prospectively? 6) Is there an explicit statement that patients were recruited consecutively? 7) Are the main findings of the study clearly described? 8) Are outcomes stratified? (e.g., by disease stage, abnormal test results, patient characteristics)?

Table 1. Adult pre- and post-myofunctional therapy outcomes. Abbreviations: % = percent, ABS = abstract, AHI = apnea-hypopnea index, BMI = body mass index, ESS = Epworth Sleepiness Scale, events/h = events per hour, kg/m^2 = kilograms per meter squared, low O2 = lowest oxygen saturation, MT = myofunctional therapy, N = number of myofunctional therapy patients in the study, PCS = prospective case series, RCR = retrospective case report, RCS = retrospective case series, RCT = randomized controlled trial, *Study authors confirmed the reported oxygen saturation data was for lowest oxygen saturation.

Table 2. Snoring outcomes based on mean values pre and post-myofunctional therapy. Abbreviations: MT = myofunctional therapy, %TST = percentage of total sleep time. Note: snoring outcomes are based on quantified definitions pre- and post-myofunctional therapy by all studies except de Paula Silva et al (case report).

Figure 1: Flow diagram demonstrating myofunctional therapy for OSA study selection. N = number of articles.

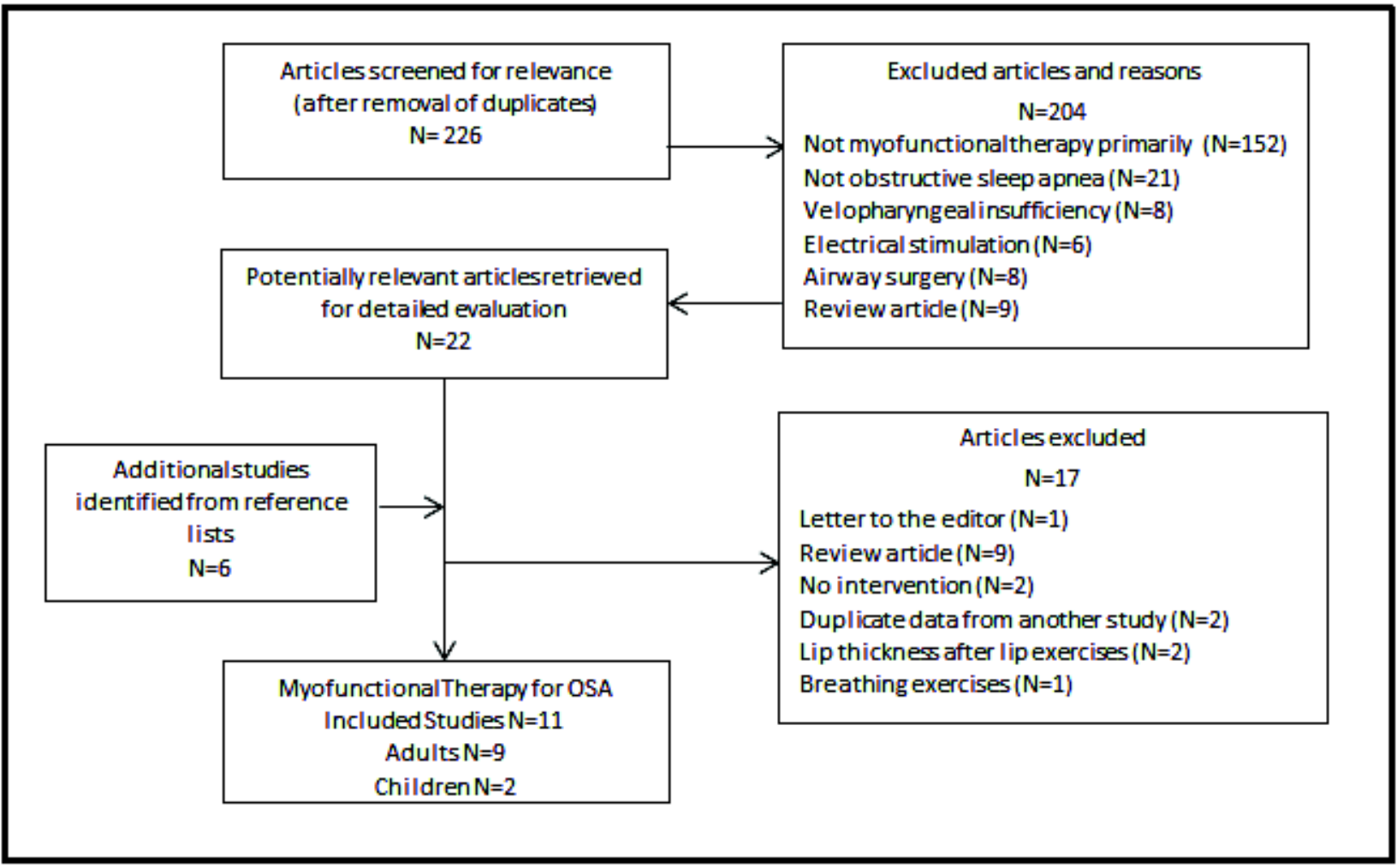
Figure 2. Adult pre- and post-myofunctional therapy outcomes for apnea-hypopnea index (events per hour). Abbreviations: CI = confidence interval, MT = myofunctional therapy, SD = standard deviation, Tx = treatment.

Figure 3. Adult pre- and post-myofunctional therapy outcomes for lowest oxygen saturation (percent). Abbreviations: CI = confidence interval, MT = myofunctional therapy, SD = standard deviation, Tx = treatment.

Figure 4. Adult pre- and post-myofunctional therapy outcomes for Epworth Sleepiness Scale. Abbreviations: CI = confidence interval, MT = myofunctional therapy, SD = standard deviation, Tx = treatment.

Study Authors Year Study Design	N	Age (years)	BMI (kg/m²)	Pre-MT AHI (events/h)	Post-MT AHI (events/h)	Pre-MT low O2 (%)	Post-MT low O2 (%)	Pre-MT ESS	Post-MT ESS
Suzuki et al.* 2013 PCS	6	22.0± 0.5	23.8± 1.8	15.1± 3.4	9.2± 1.5	90.0± 2.9	96.8± 0.8	-	-
Kronbauer et al. 2013 PCS	8	(40-65)	-	-	-	-	-	11.75	4.25
Diaferia et al. 2013 RCT	27	45.2± 13.0	25.0± 7.4	28.0± 22.7	13.9± 18.5	83.7± 7.7	84.9± 8.8	13.7± 3.2	7.5± 3.7
Baz et al. 2012 PCS	30	44.1± 7.5	33.6± 2.0	22.3± 4.5	11.5± 5.4	84± 4	87± 5	16.4± 2.0	9.3± 2.9
Guimaraes et al. 2009 RCT	16	51.5± 6.8	29.6± 3.8	22.4± 4.8	13.7± 8.5	83± 6	85± 7	14± 5	8± 6
de Paula Silva et al. 2007 RCR	1	60	23.3	44	3	83	92	-	-
Berreto et al. 2007 RCS	2	46± 12.7	24.2± 2.9	44.5± 5.7	6.0± 3.7	78± 1.4	85± 2.8	12.5± 0.7	4.5± 3.5
Guimaraes et al. 2003 ABS	10	-	-	36.1	11.3	-	-	11	7.6
Guimaraes et al. 1999 RCS	20	(33-55)	-	-	-48%	-	-	-	-
Total	120	44.5± 11.6	28.9± 6.2	24.5± 14.3	12.3± 11.8	83.9± 6.0	86.6± 7.3	14.8± 3.5	8.2± 4.1

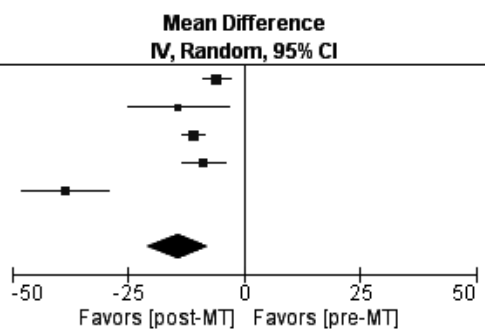
Study Authors Year	N	Subjective Snoring Pre-MT	Subjective Snoring Post-MT	PSG %TST Snoring Pre-MT	PSG %TST Snoring Post-MT
Baz et al. 2012	30	Yes = 30 No = 0	Yes = 16 No = 14	14.05± 4.89%	3.87± 4.12%
Guimaraes et al. 2009	16	Very loud	Similar to breathing	-	-
de Paula Silva et al. 2007	1	Snoring	Decreased snoring	-	-
Berreto et al. 2007	2	Disturbs bedpartner	Light snoring	-	-


Articles screened for relevance
(after removal of duplicates)
N= 226
Excluded articles and reasons
N=204
Not myofunctional therapy primarily (N=152)
Not obstructive sleep apnea (N=21)
Velopharyngeal insufficiency (N=8)
Electrical stimulation (N=6)
Airway surgery (N=8)
Review article (N=9)
Potentially relevant articles retrieved
for detailed evaluation
N=22
Additional studies
identified from reference
lists
N=6
Articles excluded
N=17
Letter to the editor (N=1)
Review article (N=9)
No intervention (N=2)
Duplicate data from another study (N=2)
Lip thickness after lip exercises (N=2)
Breathing exercises (N=1)
Myofunctional Therapy for OSA
Included Studies N=11
Adults N=9
Children N=2

Study or Subgroup	Post-Myofunctional Tx Mean	SD	Total	Pre-Myofunctional Tx Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI	Year
Suzuki 2013	9.2	1.5	6	15.1	3.4	6	23.3%	-5.90 [-8.87, -2.93]	2013
Diaferia 2013	13.9	18.5	27	28	22.7	27	14.7%	-14.10 [-25.15, -3.05]	2013
Baz 2012	11.5	5.4	30	22.3	4.5	30	23.7%	-10.80 [-13.32, -8.28]	2012
Guimaraes 2009	13.7	8.5	16	22.4	4.8	16	21.8%	-8.70 [-13.48, -3.92]	2009
Berreto 2007	6	3.7	2	44.5	5.7	2	16.5%	-38.50 [-47.92, -29.08]	2007
Total (95% CI)			**81**			**81**	**100.0%**	**-14.26 [-20.98, -7.54]**	

Heterogeneity: Tau² = 48.01; Chi² = 43.66, df = 4 (P < 0.00001); I² = 91%

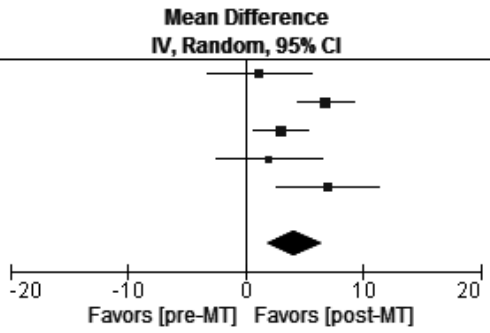
Test for overall effect: Z = 4.16 (P < 0.0001)



Study or Subgroup	Post-Myofunctional Tx Mean	SD	Total	Pre-Myofunctional Tx Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI	Year
Diaferia 2013	84.9	8.8	27	83.7	7.7	27	15.8%	1.20 [-3.21, 5.61]	2013
Suzuki 2013	96.8	0.8	6	90	2.9	6	26.0%	6.80 [4.39, 9.21]	2013
Baz 2012	87	5	30	84	4	30	26.7%	3.00 [0.71, 5.29]	2012
Guimaraes 2009	85	7	16	83	6	16	15.4%	2.00 [-2.52, 6.52]	2009
Berreto 2007	85	2.8	2	78	1.4	2	16.1%	7.00 [2.66, 11.34]	2007
Total (95% CI)			**81**			**81**	**100.0%**	**4.19 [1.85, 6.54]**	

Heterogeneity: Tau² = 4.00; Chi² = 9.74, df = 4 (P = 0.05); I² = 59%

Test for overall effect: Z = 3.50 (P = 0.0005)



Study or Subgroup	Post-Myofunctional Tx Mean	SD	Total	Pre-Myofunctional Tx Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Diaferia 2013	7.5	3.7	27	13.7	3.2	27	28.5%	-6.20 [-8.05, -4.35]	2013
Baz 2012	9.3	2.9	30	16.4	2	30	61.0%	-7.10 [-8.36, -5.84]	2012
Guimaraes 2009	8	6	16	14	5	16	6.6%	-6.00 [-9.83, -2.17]	2009
Berreto 2007	4.5	3.5	2	12.5	0.7	2	4.0%	-8.00 [-12.95, -3.05]	2007
Total (95% CI)			**75**			**75**	**100.0%**	**-6.81 [-7.79, -5.82]**	

Heterogeneity: Chi² = 1.02, df = 3 (P = 0.80); I² = 0%
Test for overall effect: Z = 13.55 (P < 0.00001)