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The Effects of Nasal Surgery on Pulmonary Function: A Systematic Review and Meta-Analysis

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Objective: A deviated nasal septum (DNS) can result in an anatomical obstruction and impact lung function through prolonged suboptimal inspiration. Given the improvements in respiration reported by patients following septoplasty or septorhinoplasty (with or without inferior turbinate reduction), our study investigated the effect of these procedures on pulmonary function through a systematic review and meta-analysis.

Data Sources: Medline, Embase, Cochrane Databases, Web of Science, and Google Scholar.

Review Methods: The review was registered with PROSPERO [CRD42022316309]. The study population was composed of adult patients (18–65) who were symptomatic with confirmed DNS. Extracted outcomes (pre-operative versus postoperative) included the six-minute walk test (6MWT) and pulmonary function tests (FEV1, FVC, FEV1/FVC, FEF25-75, PEF). Meta-analyses were performed using a random-effects model.

Results: Three studies included measures of the 6MWT in meters and all three found a statistically significant increase in the distance walked after surgery with a mean difference of 62.40 m (95% CI 24.79–100.00). Statistically significant improvements in PFT outcomes were observed with a standard mean difference of 0.72 for FEV1 (95% CI 0.31–1.13), 0.63 for FVC (95% CI 0.26–1.00), and 0.64 for PEF (95% CI 0.47–0.82). Of the twelve studies which measured PFT outcomes, six showed statistically significant improvements, three studies showed mixed results, and three studies found no difference in PFT outcomes between pre-and post-surgery testing.

Conclusions: The present study suggests that pulmonary function does improve after nasal surgery for DNS, but the high heterogeneity observed in the meta-analyses indicates that the evidence supporting this conclusion is low.

Key Words: septoplasty, rhinoplasty, deviated nasal septum, nasal surgery, pulmonary function, spirometry.

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INTRODUCTION

An estimated 75% of individuals have a deviated nasal septum (DNS), often asymptomatic and functional;[1] however, some cases result in nasal congestion, dyspnea, headaches, and an overall reduction in quality of life.[2–4] Medical therapies reducing nasal congestion and allowing for better airflow include intranasal corticosteroid spray, antihistamines, and allergen avoidance.[5,6] When medical management fails, nasal surgery may be considered, such as septoplasty or septorhinoplasty.

Septoplasties are one of the most common surgeries in Otolaryngology and can be done using an open conventional approach or an endoscopic endonasal technique.[7] Additional procedures such as inferior turbinate reduction, nasal valve repair, and/or rhinoplasty may be performed simultaneously. The degree of improvement is influenced by DNS severity, patient-specific factors, as well as the quality of post-operative care.[8] Although experiences vary, most patients report improvements in respiration after recovery.[9]

Post-operatively, improvements in respiration can be subjective, such as patient-reported shortness of breath, exercise intolerance, and daytime fatigue, or objective, including pulmonary function test (PFT) metrics and exhaled nitric oxide measurements.[10–12] Spirometry is a well-established type of PFT that is low-risk, non-invasive, and diagnostic for obstructive and restrictive lung diseases. A standard spirometry test can measure the forced expiratory volume at one second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, peak expiratory flow (PEF), and forced expiratory flow between 25 and 75% of the vital capacity (FEF25-75%).

While frequently used as a diagnostic tool for asthma and chronic obstructive pulmonary disease (COPD), spirometry can also be used to measure the impact of interventions targeting respiration. A universal example of an

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interventional (pre-post) test with spirometry is to conduct sequential testing prior to and after the administration of an inhaled bronchodilator (salbutamol) where an improvement of ≥12% and ≥200 ml in FEV1 following bronchodilator administration would indicate a diagnosis of asthma.[13,14] Interventional spirometry testing has also been used to evaluate the success of lung surgery and transplantation, as well as, the impact of physical activity on lung function decline.[15–17]

Given the improvements in respiration reported by patients following septoplasty or septorhinoplasty (with and without inferior turbinate reduction), this study aimed to investigate the effect of these procedures on pulmonary function through a systematic review and meta-analysis.[18] We hypothesized that surgical interventions to correct anatomical nasal obstructions would have pulmonary benefits as demonstrated through improved post-operative evaluation tests, namely the 6MWT and PFT metrics (FEV1, FVC, FEV1/FVC, FEF25-75, PEF).

METHODS

The study question was developed in PICO (population, intervention, control, and outcomes) format.[19] The study population was adult patients (>18 years) with symptomatic DNS (dyspnea, nasal congestion, crusting, and/or recurrent epistaxis) confirmed by endoscopy and/or CT scan. The interventions of the study were septoplasty or septorhinoplasty, with or without inferior turbinate reduction. Controls for comparison were pre-intervention (no surgery) values and outcomes were visual analog scale (VAS) and the Nasal Obstruction Symptom Evaluation (NOSE) scores, six-minute walk-test (6MWT), and measures of lung function through spirometry. This review was registered with PROSPERO [CRD42022316309] and reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.[20]

Literature Search Strategy

A medical subject librarian was consulted in the development of our search strategy. Searches were conducted in Medline, Embase, the Cochrane Database of Systematic Reviews (CDSR), Web of Science, and Google Scholar to obtain all relevant articles as of March 11, 2022. Medical subject headings (MeSH) or Embase subject headings (Emtree) were combined with various key terms (Data S1). Search results were limited to English-language articles.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) original research articles, (2) adult (18 years and older) human patients with a symptomatic DNS, (3) surgical intervention (septoplasty or septorhinoplasty with/without turbinate reduction), and (4) pre- and post-operative outcome measures of pulmonary function. Exclusion criteria were as follows: (1) post-operative outcomes measured less than 3 weeks after surgery, (2) purely aesthetic rhinoplasty interventions, (3) abstracts with no full text, and (4) opinion, editorial, and review articles.

Screening and Quality Assessment

Articles were imported into Covidence for screening by two independent reviewers (I.B. and A.P.R.).[21] Results were compared and discrepancies were resolved through a consensus discussion. Studies that met inclusion criteria were further assessed with a full-text screen. At the full-text screening stage, each excluded study was assigned a specific reason for exclusion. Finally, articles that passed the full-text screen were subjected to a quality assessment using the "NIH Quality Assessment Tool for before-after (Pre-Post) study without control group."[22] The reference lists of the included articles were reviewed for additional studies to screen.

Data Extraction

Article information (authors, year of publication, journal, study title), study information (study location, design, period, sample size, spirometry details, follow-up times, type of surgery, inclusion/exclusion criteria), patient demographics (sex, mean age), and outcomes (pre-operative versus post-operative) were extracted from the included articles. Outcomes were organized into three categories: (1) Symptom scores (VAS, NOSE), (2) six-minute walk test (6MWT) measured in meters, and (3) PFTs (FEV1, FVC, FEV1/FVC, FEF25-75, PEF).

Meta-analyses

Meta-analyses were performed using Review Manager (RevMan) 5.4.[23] Outcomes were analyzed as continuous variables using inverse variance weighting and a random effects model given the expected heterogeneity of the included studies. The effect measure for the 6MWT was the mean difference as all included studies used the same outcome units (meters). The remaining outcomes were reported in different units so standardized mean differences were used.

Handling of Missing Data

The RevMan 5.4 software requires means and standard deviations (SD) to conduct the required analysis. In cases where only median, range, and sample size were reported (mean and SD not available), the Box-Cox transformation method was used to estimate the mean and SD.[24,25] When none of these measures were available, the corresponding author was contacted, with a follow-up 1 week after initial contact if there was no reply. If there was no reply 2 weeks from initial contact, the studies could not be included in the meta-analyses and results.

Literature Search

The literature search and screening process is presented in Figure 1. The combined database searches yielded 1922 records. After the removal of duplicates, there were 1727 records that underwent title and abstract screening. The full-text review was performed on 62 articles, from which 49 were excluded (Fig. 1). All 13 included studies passed the NIH Quality Assessment (Table S1). Out of the 13 included studies, one did not have SD or ranges reported,[26] which left 12 studies for meta-analyses. No additional studies were identified from the reference lists of the included studies.

Included Studies

Characteristics and outcome summaries of the 13 studies are presented in Table I.[2,26–37] The included studies were published between 2010 and 2021. Geographically, most of the studies were from Turkey (6/13, 46%) and India (5/13, 38%), with the remaining two from Egypt (2/13, 15%) (Table I). The majority of

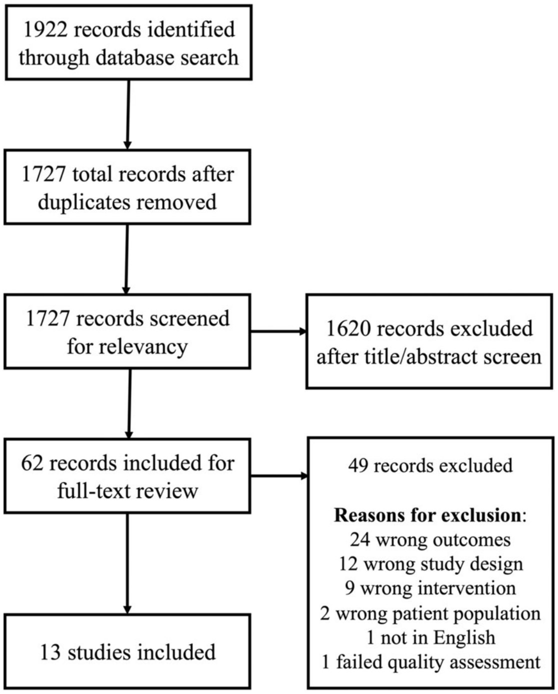

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow chart displaying the screening process for included and excluded studies.

included studies (9/13, 69%) were from journals indexed in reputable databases (PubMed, EMBASE, SCOPUS, Web of Science),[2,26,28,30,32–34,37] the remaining (4/13, 31%) were found in Google Scholar.[27,29,31,35,36]

All included articles followed an interventional pre-post-study design. The number of participants included in the studies ranged from 14 to 90. A total of 583 patients were enrolled across all the articles with 561 completing the follow-up testing. All but one study[33] had more male participants than female participants. In total, there were 351 males and 180 females. Patient sex was not reported for the 30 participants in the study by Arivazhagan et al.[29]

Follow-up times ranged from 1 to 6 months post-operation. In general, the study-specific inclusion criteria were more similar than the exclusion criteria, with some studies excluding combination nasal surgeries and others including patients undergoing concurrent inferior turbinate reduction. The majority of included studies (8/13, 62%) limited the surgical intervention to septoplasty, excluding participants who underwent other concurrent nasal procedures (Table I). Three studies included participants who all received septoplasty but may have had additional procedures (+/− inferior turbinate reduction or sinus surgery) and two studies included participants who had either a septoplasty or another nasal surgery (septorhinoplasty, inferior turbinate reduction, sinus surgery, or nasal polypectomy) (Table I).

Symptoms Scores

Three studies included validated symptom scores (3/13, 23%). Ogreden et al[26] reported a statistically significant improvement with a reduction of 5.375 in the nasal obstruction grades assessed by VAS post-operation (SD and 95% CI not available). Elsherif et al[31] presented a post-operative VAS of 8.66 (SD: 0.875), however, no pre-op VAS was included such that quantifying improvement was not possible. A statistically significant improvement in NOSE scores post-operation was reported by Tuzuner et al[2] with a pre-operative median NOSE score of 14 out of 20 (range: 10.8–16.0) and post-operative median NOSE score of 4 out of 20 (range: 0.8–6.3). Multiplying these scores by five to get the conventional scale (out of 100) results in a pre-operative median score of 70 (scaled range: 54–80) and post-operative median score of 20 (scaled range: 4–31.5).

Six-minute Walk Test

Three studies included measures of the 6MWT in meters (3/13, 23%) with testing happening at different periods post-operatively (1-, 2-, and 6-month) in each study (Table I).[2,27,31] The remainder of the studies did not include the 6MWT as an outcome.

A forest plot of these studies is presented in Figure 2. The mean change in the 6MWT was an increase of 62.40 m (95% CI: 24.79–100.00) post-nasal surgery. Improvements in the mean distance ranged from 40.84 to 132.94 m. This analysis had a high heterogeneity value ($I^2 = 75\%$) despite similar study design, participants, interventions, and outcomes measured. The observed heterogeneity might be attributed in part to the lower sample size in the study by Akinoglu et al[27] ($n = 17$), however, additional details about the walk test protocols were not available.

Pulmonary Function Test

There were 12 studies with PFT outcomes (12/13, 92%) (Table I). The only article that did not have any measures of PFT reported 6MWT outcomes.[27] The studies varied in the PFT measures collected. All 12 studies reported FEV1 and 11 studies reported FVC values while only six and five articles reported PEF and FEF25-75 values, respectively (Table I).

Statistically significant improvements in all PFT outcomes measured were observed in six out of 12 studies (Table I). Three studies showed mixed results for the varying PFT outcomes (Table I). For example, Tuzuner et al[2] found a statistically significant improvement in PEF but found no significant differences in FEV1, FVC, FEV1/FVC, and FEF25-75 between pre-and post-operative values. Three studies found no significant difference in the PFT outcomes measured between pre-and post-operative spirometry at follow-up (Table I).[32,35,37]

Forest plots for PFT outcomes are presented in Figures 2–4. 4. Meta-analyses included all studies with available data. For FEV1 and FVC, the standard mean differences were 0.72 (95% CI: 0.31–1.13) (Fig. 2) and 0.63 (95% CI: 0.26–1.00) (Fig. 3), respectively. In both cases, patients showed improvements after surgery, but the heterogeneity values were high with I^2 values of 89% for FEV1 and 86% for FVC. There were moderate to high heterogeneity values for all variables except for PEF. The standard mean difference in the PEF was an increase of 0.64 (95% CI: 0.47–0.81) post-operatively with homogeneity among the studies for this outcome ($I^2 = 0\%$) (Fig. 3). A difference in effect measure of 0.51 was observed for FEF25-75 but confidence intervals were near zero between the pre-and post-operative spirometry results (95% CI: 0.01–1.00) (Fig. 4). Finally, no significant difference was observed for FEV/FVC values between pre-and post-operative values (standard mean difference: 0.44, 95% CI: −0.07 to 0.96) (Fig. 4).

Subgroup Analyses

Subgroup analyses were performed to elicit the causes of heterogeneity among PFT results. The included studies did not stratify results by patient sex, age groups, or surgical

TABLE I.
Summary of Included Studies Investigating the Effects of Nasal Surgery on Objective Measurements of Pulmonary Function.

First Author (Year)	Study Location	Study Size	M/F	Mean Age (SD)	Follow-up (Months)	Surgery	Pulmonary Function Tests			6MWT	
							Improved	NS	NA	Improved	NA
Akinoglu (2017)	Ankara, Turkey	37 enrolled, 17 completed	13/4	27.5 (7.8)	6	SP			◉	◉†	
Arifa (2021)	Karnataka, India	90 enrolled, 88 completed	64/24	29.9 (NA)	1	SP +/− ITR	FEV1†, FVC†, FEV1/FVC†, PEF†				◉
Arivazhagan (2019)	Puducherry, India	30 enrolled, 30 completed	NA	NA	1	SP	FEV1†, FVC†, FEV1/FVC*, FEF25-75†, PEF†				◉
Bulcun (2010)	Ankara, Turkey	14 enrolled, 14 completed	10/4	29.9 (11.6)	2–3	SP	FEV1*, FVC*, PEF*	FEV1/FVC			◉
Elsherif (2019)	Kafr-el Sheikh, Egypt	60 enrolled, 60 completed	36/24	23.9 (5.9)	2	SP	FEV1†, FVC†, FEV1/FVC†			◉†	
Erdogdu (2019)	Istanbul, Turkey	35 enrolled, 35 completed	27/8	28.2 (10.0)	1	SP +/− ITR +/− SS		FEV1, FVC, FEV1/FVC			◉
Mandour (2019)	Banha and Kafr El Sheikh, Egypt	90 enrolled, 90 completed	39/51	26.7 (9.5)	2	SP +/− ITR	FEV1†, FVC†, FEV1/FVC†, FEF25-75†, PEF†				◉
Nanda (2019)	Himachal Pradesh, India	50 enrolled, 50 completed	27/23	NA	1	SP	FEV1*, FVC*	FEV1/FVC			◉
Ogreden (2018)	Istanbul, Turkey	53 enrolled, 53 completed	44/9	NA	6	SP	FEV1†, FVC†, FEV1/FVC†				◉
Ozel (2011)	Ankara, Turkey	9 enrolled, 9 completed	5/4	36.8 (13.4)	3	SP or ITR or SS or NP		FEV1, FEF25-75			◉
Panicker (2018)	Karnataka, India	35 enrolled, 35 completed	25/10	NA	1.5	SP or SRP	FEV1†, FVC†, FEV1/FVC†, FEF25-75†, PEF†				◉
Singh (2020)	Mullana, India	50 enrolled, 50 completed	39/11	NA	1	SP		FEV1, FVC, FEV1/FVC			◉
Tuzuner (2016)	Ankara, Turkey	30 enrolled, 30 completed	22/8	33.4 (10.9)	1	SP	PEF†	FEV1, FVC, FEV1/FVC, FEF25-75		◉†	

$^{*}p < 0.05$.
$^{\dagger}p < 0.001$.
FEF25-75 = forced expiratory flow between 25 and 75% of the vital capacity; FEV1 = forced expiratory volume at one second; FVC = forced vital capacity; ITR = inferior turbinate reduction; M/F = male/female; NA = not available; NP = nasal polypectomy; NS = no significant difference; PEF = peak expiratory flow; SD = standard deviation; SP = septoplasty; SRP = septorhinoplasty; SS = sinus surgery.

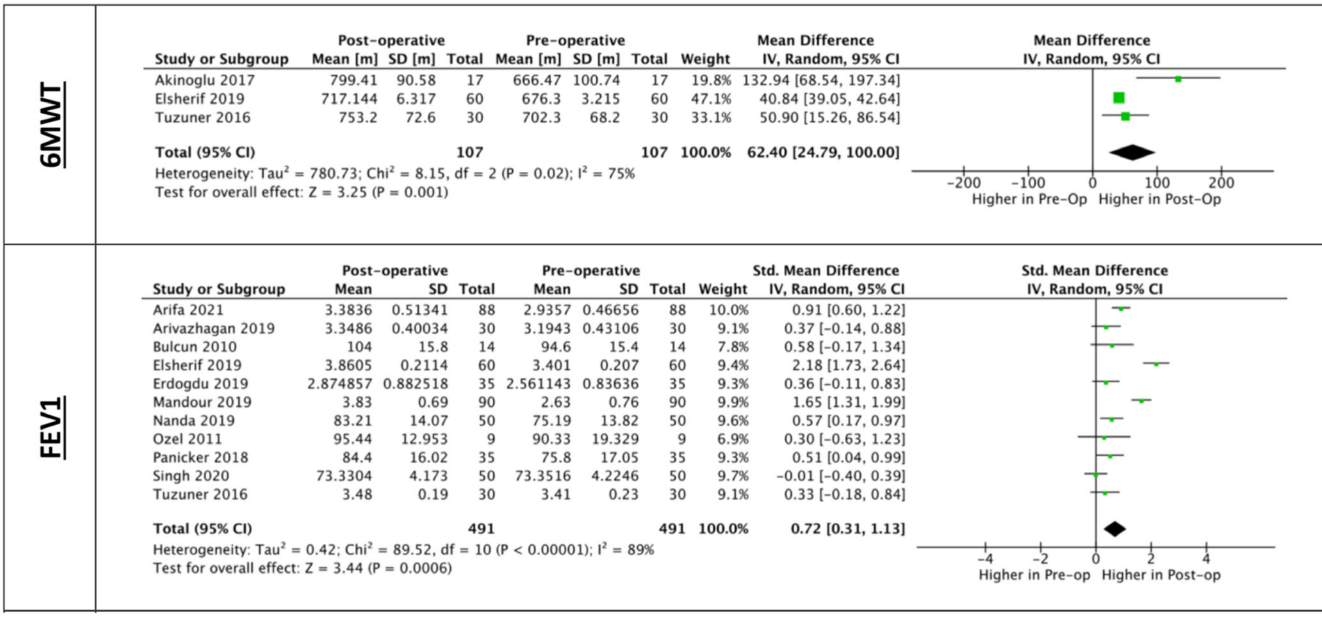

Fig. 2. Summary measures and forest plot of the change in outcomes of six-minute walk test (6MWT) and forced expiratory volume at one second (FEV1) from pre-operative to post-operative measures in patients who underwent nasal surgery. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

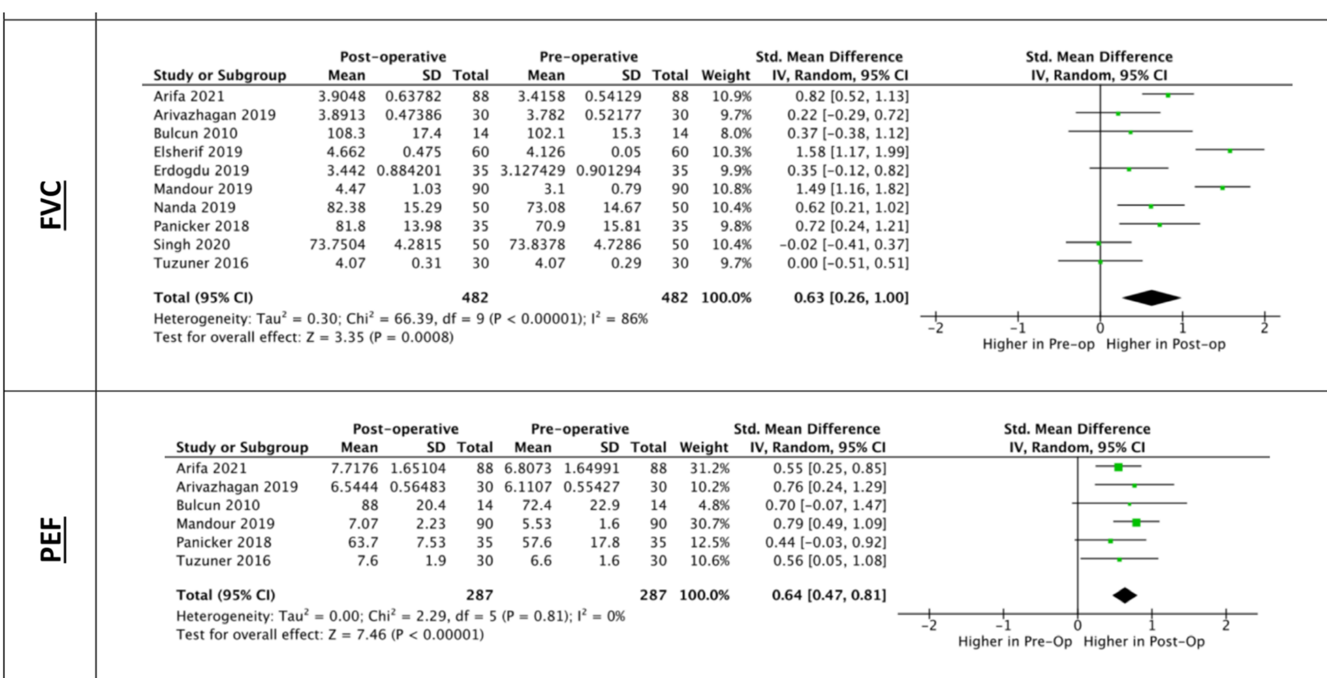

Fig. 3. Summary measures and forest plot of the change in outcomes of forced vital capacity (FVC) and peak expiratory flow (PEF) from pre-operative to post-operative measures in patients who underwent nasal surgery. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

intervention (i.e., septoplasty, septorhinoplasty, with/without inferior turbinate reduction) so subgroup analyses for these parameters could not be done. Similarly, pre-specified subgroup analysis between asthmatic and non-asthmatic patients was also not possible due to a lack of patients with concomitant asthma. Post-hoc subgroup analyses of the Country of Study were performed after it was observed that all included studies were limited to three countries (India, Egypt, and Turkey).

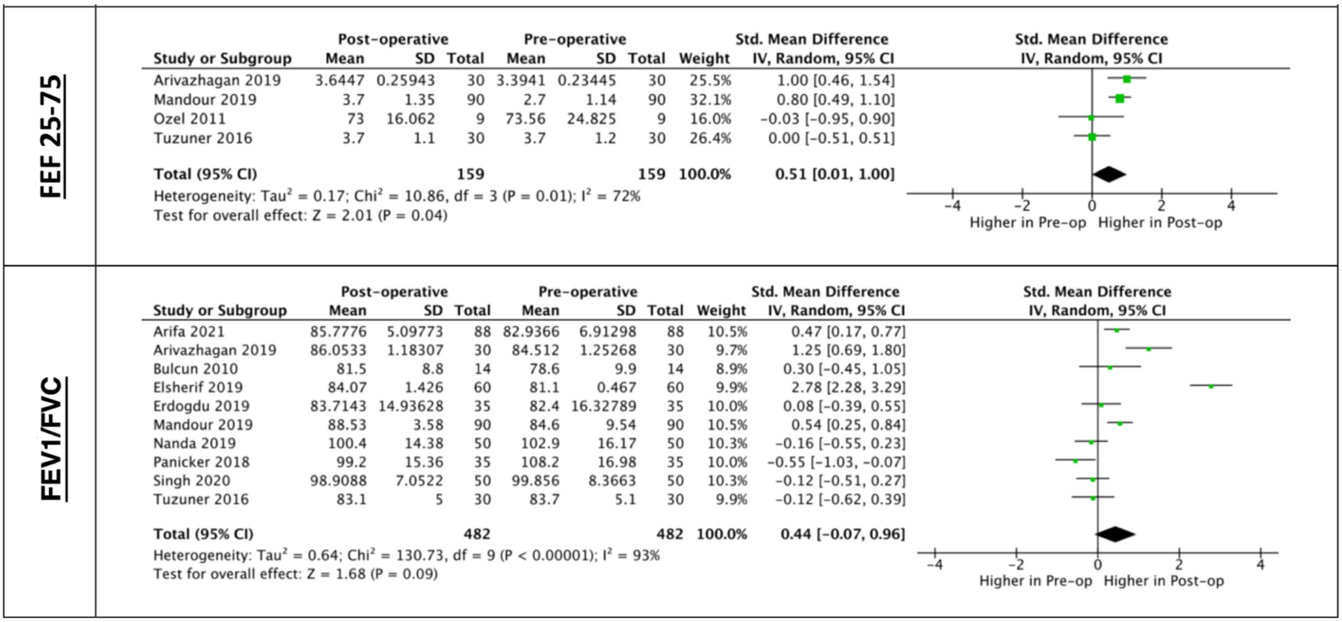

Fig. 4. Summary measures and forest plot of the change in outcomes of forced expiratory flow between 25 and 75% of the vital capacity (FEF25-75) and FEV1/FVC from pre-operative to post-operative measures in patients who underwent nasal surgery. FEV1 = forced expiratory volume at one second, FVC = forced vital capacity. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

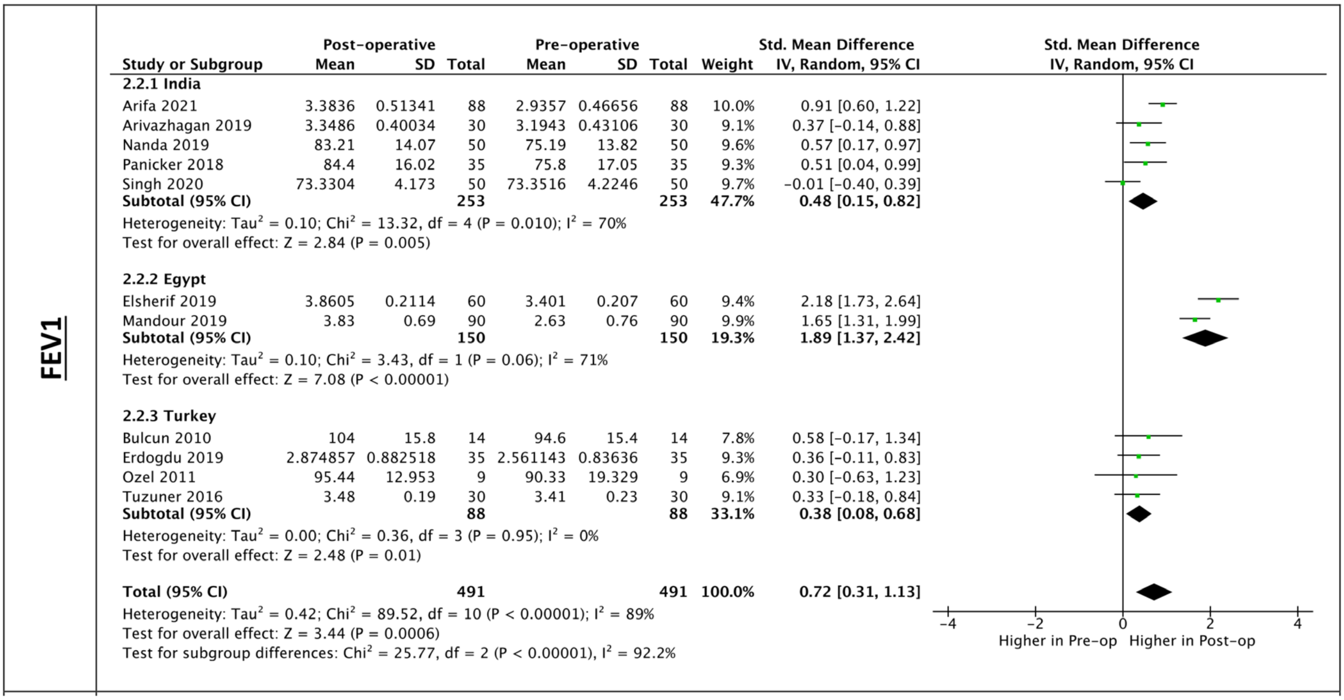

Fig. 5. Country subgroup analyses of the change in outcomes of forced expiratory volume at one second (FEV1) from pre-operative to post-operative measures in patients who underwent nasal surgery. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

The test for subgroup differences was statistically significant for both FEV1 ($\chi^2 = 25.77$) (Fig. 5) and FVC ($\chi^2 = 46.36$) (Fig. 6). However, there was substantial heterogeneity within some subgroups ($I^2 \geq 70$) while others were homogenous. Subgroup analyses for 6MWT, FEF25-75, and PEF could not be carried out due to single study groupings with one study per country reporting these outcomes.

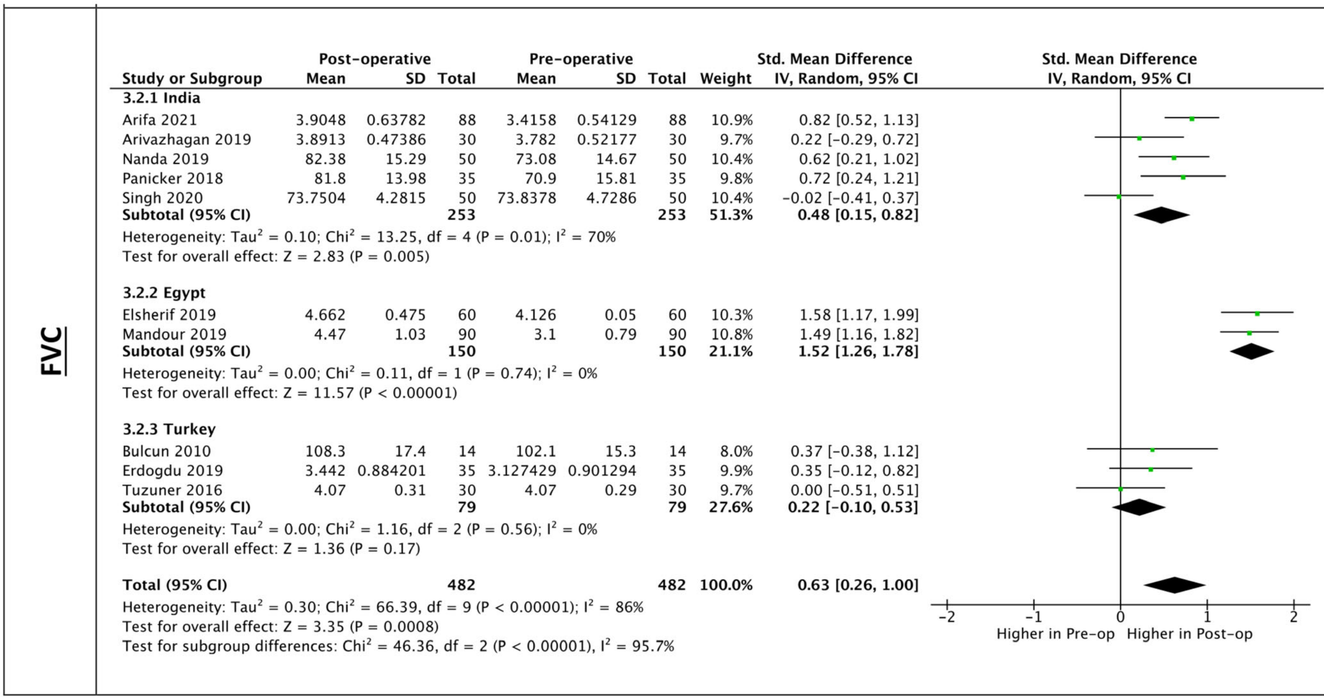

Fig. 6. Country subgroup analyses of the change in outcomes of forced vital capacity (FVC) from pre-operative to post-operative measures in patients who underwent nasal surgery. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

DISCUSSION

The purpose of this review was to assess potential improvements in lung function after nasal surgery in patients with symptomatic DNS through PFT and 6MWT. Overall, associated improvements were seen in all domains assessed. There were statistically significant improvements seen in the 6MWT as well as PFT, although significant heterogeneity was found between groups. Subgroup analysis was conducted to elucidate an explanation for the heterogeneity observed among studies. Country subgroup analysis only demonstrated a statistically significant difference for FEV1 and FVC outcomes with the greatest improvement seen in studies conducted in Egypt. Observed country grouping might be explained by different pre-and post-operative protocols, variations in surgical technique or PFT standardization, as well as study participants between the three countries.

The inclusion and exclusion criteria removed papers only measuring symptom scores such as VAS, NOSE, and SNOT-22 in the absence of any lung-specific outcomes. However, the three included studies that did measure symptom scores showed a statistically significant improvement in these variables following surgery which is in line with several other studies that validated these instruments.[38–40]

Despite being treated by two different medical specialties, otolaryngology, and respirology, the nose and lungs share anatomical and histological features including ciliary epithelium, goblet cells, and basement membrane.[18,41] Giavina-Bianchi et al[18] provide a comprehensive review of the epidemiologic, pathophysiological, and clinical evidence of the link between the upper and lower airways, described as the unified airway disease (UAD) hypothesis.[42] One proposed approach to understanding the pathophysiology of UAD involves characterizing the interactions as affecting air-humidification, inflammation, and neural reflexes.

To date, the major focus of UAD research has been on describing the link between rhinitis and asthma.[43,44] Meena et al. 2013 describe additional links between the upper and lower airways through the nasobronchial reflex (bronchoconstriction response caused by irritant stimulation of nasal mucosa) and the pharyngobronchial reflex (bronchoconstriction response due to sinus secretions irritating the hypopharynx).[45] A previous systematic review and meta-analyses involving chronic rhinosinusitis (CRS) and asthmatic patients found low-quality evidence for improvements in PFT outcomes following endoscopic sinus surgery (ESS) in CRS patients with concomitant asthma.[46]

Unlike the example of rhinitis with concomitant asthma, studying the impact of a DNS on pulmonary function is more anatomical than cellular and immunological. A DNS primarily results in a physical obstruction and thus impacts lung function through prolonged periods of sub-optimal inspiration.[28] Nasal obstruction results in mouth breathing, negating the nose's warming and humifying process and subsequently changing pulmonary surfactant viscosity, causing bronchial constriction.[28,47]

The primary outcome of this review was PFT (spirometry) changes. Despite the relative ease and low risk of spirometry testing, pre-post PFT evaluation is not routinely conducted in patients undergoing nasal surgery as it does not alter the clinical course of treatment and begets added costs to the healthcare system. The oldest study included in our review was from 2010, demonstrating the relatively new use and reporting of such outcomes in assessment of post-surgical improvements. Anterior rhinomanometry is another evaluation technique that can be performed post-operatively, measuring unilateral airflow through the nose.[48,49] However, anterior rhinomanometry does not offer information about changes in lung function which was the outcome of interest in our study.

There has been a long-standing debate regarding the definition of significant improvements in spirometry readings.[50–52] The current criteria state that a 12% improvement in FEV1 or FVC following bronchodilator use is a clinically significant improvement and can be indicative of reversible airway obstruction (e.g., asthma).[52] Based on this criterion, the included studies showed combinations of statistically and/or clinically significant improvements in spirometry measures post-nasal surgery. Unfortunately, participant-specific data were unavailable to evaluate the percentage of participants that showed clinically significant improvements versus those that did not. There were also cases of statistically significant improvements without the difference meeting the 12% threshold of clinical improvement.

The second outcome evaluated in this review was the 6MWT, described by the American Thoracic Society as a measure of functional status or fitness.[53,54] This method is efficacious and easily reproducible as it is at low risk to the patient and does not require specialized equipment. Improvements were observed in the overall distance walked during the 6MWT post-operatively. Functionally, the mean improvement of 62.42 m observed in this study has been shown to be clinically significant.[55]

Limitations of this study, as previously mentioned, included the significant heterogeneity values observed in the meta-analyses with regards to the measured outcomes, which could partly be attributed to differences in geographic location among studies. Another limitation was the lack of high-quality studies published in top-tier journals meeting the inclusion/exclusion criteria. Despite an extensive search strategy, only 13 studies were identified, all of which varied in the outcomes measured. Additionally, none of the studies included a control group nor was there any blinding of outcome assessors. Further, septoplasty and septorhinoplasty were grouped together in this study, not accounting for the significant differences in functional procedures and maneuvers between the two surgeries. Furthermore, the differences between the type of turbinate surgery and subsequent effects on the nasal valve, nasal cycle phenomena, among other parameters were unable to be elucidated.

The studies included did not control for confounding interventions which could account for improvements in pulmonary function unrelated to the surgical intervention observed, including but not limited to lifestyle changes like increased physical activity and improved fitness over the study period. Similarly, there may have been contributions to improved outcomes from non-surgical interventions such as steroids, biologics, or office-based procedures (polypectomy) that were not reported in the included studies. Finally, it was not clear how many surgeries had failed or led to complications and how these events were dealt with statistically.

Despite these challenges, this review contributes new knowledge to an understanding of the connection between the upper and lower airways and the pulmonary benefits provided to patients post-nasal surgery. Future studies of higher methodological quality should include a more comprehensive set of parameters to improve evidence and better clarify the pulmonary benefits achieved following nasal surgery, with investigation of concomitant pathologies, such as patients with asthma.

CONCLUSION

Our study found low-quality evidence for an association between nasal surgery and improvements in lung function in patients with symptomatic DNS. There were statistically significant improvements seen in the 6MWT as well as PFT (FEV1, FVC, PEF, and FEF25-75%), although significant heterogeneity was found between study groups. Future studies with rigorous, high-quality methodology are required to support this conclusion. Moreover, future interventional pre-post studies could also examine the improvements in PFT for patients who have a DNS with concomitant asthma.

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