The effects of vocal function exercises on the lung function of trained female singers.

A pilot investigation

K. Price B Sc. (Clin. Sc)

C.Gosling B App Sc. (HM) Grad Dip (Ex Rehab) M App Sc. (Research)

School of Health Sciences, Victoria University,

Melbourne, Australia

ABSTRACT

Vocal function exercises have been designed to strengthen and tone the muscles of the larynx and supporting musculature to enhance vocal function. The effect of these exercises on lung function is yet to be determined. Ten trained female volunteers participated in the current pilot study. All ten subjects performed vocal function exercises twice daily over a period of four weeks and their lung function was tested at the beginning and end of the four week period using Forced vital capacity (FVC), forced expiratory volume in once second (FEV_1), FEV_1/FVC ratio. Significant differences were found in both FEV_1 ($p = 0.013$) and FEV1/FVC ratio ($p = 0.009$) after the completion of the exercises. This it most likely attributed to an increase in the power of the inspiratory muscles and greater muscular co-ordination, strength and endurance during exhalation.

KEY WORDS

Vocal function exercises, lung function, FEV_1.

INTRODUCTION

An efficient vocal system uses a balance of airflow and laryngeal muscle activity [1]. Vocal exercises can be used to enhance the function of this system. A particular set of exercises known as vocal function exercises (VFEs) have been designed to strengthen and balance the laryngeal musculature, improve vocal fold vibration and movement and optimize air usage and muscular activity[1]. Research has shown positive effects on the phonatory systems of singers when using these exercises[2,3]. The reported positive physiological effects of VFEs included altered phonation volumes, airflow rates and maximum phonation times[2,3].

Phonation or voice production involves the making of sounds that can be varied in pitch, intensity and quality. The sounds are produced as air from the lungs passes through the vocal chords thus producing a functional link between the lower respiratory system and the larynx. The lower respiratory tract is required for the completion of these exercises however the effect on this component of the system has yet to be determined.

Vocal Exercises

Many singers' practice regimes consist of a variety of exercises. It has been noted that there are three types of vocal exercises: isometric, isotonic and callisthenic. *Isometric* exercises consist of a sustained contraction, for example a specific pitch begun with a crescendo, sustained at a forte dynamic and then ended with a diminuendo[1]. *Callisthenic* exercises are composed of numerous short muscle contractions and *isotonic* exercises allow the muscle to change length at a very slow rate[1]. VFEs

incorporate both isotonic and isometric exercises and are designed to give the respiratory and laryngeal musculature a refined workout at a very soft dynamic[2].

VFEs have been shown to improve the phonation systems of singers and the greatest benefits have been achieved close to the extremes of the pitch levels[1,2]. Phonatory ability and efficiency depend on pulmonary efficiency, which may be evaluated by a variety of pulmonary function tests (PFT). This study focussed on the effect of VFE training on pulmonary function.

Lung Function in Trained Singers

There are conflicting opinions as to whether vocal training results in a superior pulmonary function in trained singers. Some studies have shown there to be no differences between singers and non-singers[4,5]. While Carroll et al[6] suggest that due to their training, singers have a greater pulmonary function and therefore a separate set of normative data is required in order to assess the vocal athlete. Gould[7] also supported the notion that singers have developed an increased pulmonary function and suggested that this is due to trained singers having a reduced residual volume/total lung capacity (RV/TLC) ratio. That is, their vital capacity is expanded at the expense of their residual volume resulting in an increased breathing capacity.

The very function of an exercise protocol is to nurture an effect in the participating cohort. Previous studies have identified VFEs to have a training effect on aerodynamic and acoustic outcomes[1-3] but none have investigated their effect on lung function measures. Singers were chosen as the cohort for this study due to their

familiarity with vocal exercises of various natures. Changes we observe in outcome measures should be able to be attributed to the effect of the intervention protocol.

The Effect of Vocal Function Exercises on Voice Production

The effect of VFEs on voice production has been investigated previously[2]. The parameters measured included, acoustic and aerodynamic analysis (fundamental frequency, jitter, phonation volume, flow rate and maximum phonation time), frequency range and videostroboscopic analysis. Significant pre- and posttest differences between experimental and control groups for *acoustic and aerodynamic analysis* ($p=0.006$) were found, however no significant differences were found in pre- and posttest analysis of *frequency range* or *videostroboscobic analysis*. These results may have been attributed to the fact that the experimental group in this study ($n=10$) had low compliance with only six members of the group performing the exercises over the entire four weeks of testing.

Similar results were obtained by Stemple, Lee, D'Amico and Pickup[3]. In this study pre- and posttest analysis of both *acoustic and aerodynamic analysis* and *frequency range* were found to be significant. Once again, no significance was found in pre- and posttest analysis of *videostroboscopic analysis*. This non significant change in videostrobic analysis indicates that VFEs do not alter vocal cord function and some other mechanism may be responsible for the increase in acoustic and aerodynamic functions.

The primary physiologic effects of VFEs in these studies were reflected in altered phonation volumes, airflow rates, maximum phonation times and frequency ranges[2,3].

It has been postulated that the increase in phonation volume and maximum phonation time may have been due to an increase in respiratory muscle strength thereby improving ventilatory strength, coordination and endurance. It was suggested that subjects also may have learned to inspire to a higher percentage and expire to a lower percentage of their vital capacities thereby increasing the amount of available lung capacity[3,7]. A significant decrease in posttest airflow rates also contributed to the increase in phonation volume. Sabol, Lee and Stemple[2] attributed the decrease in airflow rates to improved vocal chord tone and coordination of laryngeal timing.

The authors of these two studies indicate that the VFEs had some effect on the larynx, muscles of respiration and vocal chords. The functional and anatomical link between the upper and lower respiratory tracts provides a means by which the effects of VFEs may also be observed in pulmonary function. However without microelectrode EMG studies of the respiratory musculature it is hard to speculate on cases of these changes to pulmonary function.

Clinical investigations on the effect of ventilatory muscle training on exercise capacity and pulmonary volumes in patients with chronic obstructive airways disease (COPD) has been established[8,9]. Improved ventilatory muscle performance and submaximal exercise endurance was observed in this patient population with inspiratory muscle training. Although there is dispute as to whether singers have a greater pulmonary function to begin with, or whether training improves it, the effect of VFEs on gold standard lung function parameters is yet to be determined. An increase in pulmonary function may provide a useful adjuct to conventional therapy in patient populations, especially those with COPD.

VFEs have previously been postulated to improve larynx musculature and vocal cord function[1,2]. There is currently no published findings on the effects of VFEs on lung function parameters in a cohort of trained singers. The current study aimed to test whether VFEs that were designed to train the larynx and supporting musculature, improved lung function.

METHOD

Participants

Trained volunteer female vocalists (N=10) from the Melba Conservatorium of Music participated in this study. Nine volunteers successfully completed the study there was one withdrawal. . All were non-smokers with no history of laryngeal pathology or current voice disorder. All participants had at least three years of voice training and all were encouraged to continue their regular practice regimes throughout the duration of the testing. Each participant received both a written and verbal explanation of the study. Informed consent was obtained from each subject and the study was approved by the Victoria University Human Ethics committee.

Questionnaire

Prior to commencement each volunteer completed a questionnaire comprising information about vocal history and current voice training. This included questions about age, voice usage, extracurricular singing activities and details about regular singing practices.

Exercise Procedure

The same investigator trained the volunteers in the proper technique for performing the VFEs as outlined by Stemple[1]. They consist of four parts:

1. **Warm up:** Sustain the musical note F (above middle C) for as long as possible on the vowel "E".
2. **Stretching exercises:** Glide from your very lowest note to your very highest note on the vowel "O".

3. **Contracting exercises:** Glide from your very highest note to your very lowest note on the vowel "O".
4. **Power exercises:** Sustain the musical note middle C-D-E-F-G for as long as possible on the vowel "O".

Participants were required to perform each exercise twice in a row, two times per day as outlined by Stemple[1]. Compliance was an issue raised in a previous study[2]. The volunteers recorded exercise performance in a logbook for verification. The same investigator met with the experimental group on a weekly basis to revise the VFEs.

Measures

Data collection was undertaken on two occasions, 28 days apart at the same time of the day in accordance with previous studies using the VFE protocol[2,3]. Subjects were seated quietly in the testing room throughout the data collection period.

Pulmonary Function Testing (PFT): Participants were able to familiarize themselves with the equipment prior to the commencement of data collection. The procedure for taking FVC and FEV_1 measurements followed the American Thoracic Society's guidelines: 1994 Update[10]. Lung function was measured using a wedge bellows spirometer (Vitalograph: error ± 1%), which was calibrated using a one litre syringe at the beginning of the testing day and between each volunteer. Each participant took a maximum forced inspiration followed by a maximum forced exhalation until no more could be exhaled. A minimum of three technically acceptable ventilatory maneuvers was performed. If there was large variability between expiratory maneuvers up to eight acceptable FVC maneuvers were allowed[10]. Participants were encouraged to squeeze out all of the air in their lungs at the end of the maneuver. "End of test" occurred when there had been no change in volume for at

least two seconds, or when for clinical reasons, the participant could not or should not continue further exhalation. Participants wore a nose peg during testing. A minimum exhalation time of six seconds was required[10].

Statistical Analysis

Data is presented as mean ± standard deviation. The data was analysed using SPSS Version 11 (Microsoft, USA) for significance between groups. The parameters measured were FVC, FEV_1 and the FEV_1/FVC ratio. A two-tailed t-test for dependent means was used to determine significance between groups. Significance was set at $p \leq 0.05$. Cohen's d for effect has also been calculated for each parameter. Compliance was determined by the number of exercise sessions performed versus the number prescribed. Pearson's R was calculated to determine the correlation between participant compliance and percentage increases in FEV_1 and FEV_1/FVC ratio.

RESULTS

Questionnaire

The questionnaire revealed no gross differences in the practice regimes of the participants (average hours per week: 6.18 ± 1.88 hrs). Number of years of formal classical training ranged from three to 14 years (9.11 ± 3.7 yrs)

Lung function

Pre and posttest means and standard deviations for lung function testing are contained in table one. There was no significant pre- and posttest differences in FVC ($t = -0.34$, $p = 0.737$). FVC also demonstrated a small effect size ($d = 0.20$). There were significant pre and posttest differences in FEV_1 ($t = -2.66$, $p = 0.013$). Subjects' mean FEV_1 increased from 2.65 to 2.88 L/sec. Effect size was also large for this parameter ($d = 0.98$). The results of the FEV_1/FVC ratio also revealed significant pre- and posttest differences ($t = -2.82$, $p = 0.009$) increasing from 80 to 85% with an effect size of 0.65.

Insert table 1 near here.

Subject compliance

Nine of the ten original subjects successfully completed the study. The average proportion of exercise completion was 79.11% (± 11.41). Only one subject completed all scheduled exercise times.

Correlation

Correlations between compliance and the percentage increase in FEV_1 was calculated at $R = -0.44$ ($p = 0.235$) and between compliance and the percentage increase in FEV_1/FVC ration at $R = -0.47$ ($p = 0.204$).

DISCUSSION

Results of this investigation indicate that there were significant positive changes in the participant's lung function resulting from the daily addition of VFEs to their regular singing practice regime. Improvement was reflected in FEV_1 and the FEV_1/FVC ratio. Sabol et al [2] postulate that the VFEs increase the power of the inspiratory muscles and increase muscular co-ordination, strength and endurance during exhalation, which may explain the improvement in FEV_1.

It is likely that the significant increases observed in FEV_1 and the FEV_1/FVC ratio from baseline was due to the introduction of the VFEs rather than the experimental cohort being trained vocalists. The baseline values of FVC, FEV_1 and FEV_1/FVC for the current study were no greater than those reported in a normal healthy population group[11].

Pulmonary function has not been well studied in trained singers. Carroll et al[6] concluded that trained singers have a greater pulmonary function than the general population, while Heller et al[4] and Schorr-Lesnick et al[5] described no difference in pulmonary function to the general population. Participants included in this study had completed a minimum of three years of formal classical training (ranging from three to 14 years: 9.11 ± 3.7 yrs) similar to the cohort described by Carroll et al[6]. Our study cohort demonstrated no difference in pulmonary function values from the expected for the general normal population. The numbers of participants used in this study was not sufficient to make any conclusions about whether trained vocalists have an improved starting pulmonary function or whether it is a long term training effect.

Fine motor control and optimum tone of the muscles of the larynx are vital for voice production, especially in classical singing. Strength and power of respiratory muscles during exhalation are of equal importance. Previous studies investigating VFEs have measured parameters of vocal function and voice production[2,3]. These included acoustic and aerodynamic analysis (fundamental frequency, jitter, phonation volume, flow rate and maximum phonation time), frequency range and videostroboscopic analysis. The significant changes observed in these studies may not only be due to an increase in strength and tone of the muscles of the larynx, but also due to a greater ability to expel air quickly as reflected in the results of the current study. The main variables altered were phonation volumes, airflow rates, maximum phonation times, and frequency ranges. Our study showed improvement in pulmonary function as measured by increases in FEV_1 and the FEV_1/FVC ratio. This could manifest in positive outcomes in all of the previously measured variables.

A moderate correlation between compliance and percentage increase in FEV_1 ($R=-0.44$) and FEV_1/FVC ($R=-0.47$) ratio was observed, although these were not significant. This indicates that increases in lung function were observed inspite of only moderate compliance in this participant population. The current study used a timeframe implemented by previous investigators interested in parameters of vocal function[2,3]. The effects of VFEs on pulmonary function may be observed with fewer exercises sessions over a shorter period, although further investigation is required to determine the optimum timeframe for implementation of the exercises when using them to improve vocal and lung function.

Similarly, compliance was an issue raised by Sabol et al.[2]. Data in their study was only reported over a three week period not four as initially intended. Compliance was only 60 percent in the fourth and final week therefore the investigators did not report this data. Instead weeks one and three were compared using a t-test because all 10 experimental subjects performed the exercises for three complete weeks. No comparison can be made between this study and compliance in the current study as data from the fourth week, where compliance was only 60 percent, was not reported. The results reported in this study indicate that as little as three weeks may be sufficient to observe the changes implemented by VFEs[2].

No significant increase in FVC was observed in the current study which may be due to the four week duration of the exercise regime. Gould concluded that singers have a higher FVC at the expense of their RV/TLC ratio[7]. Long term VFE training may result in a subsequent increase in FVC and decrease in the RV/TLC ratio, but further longitudinal controlled testing is required to investigate this hypothesis.

Some factors were not controlled as a consequence of the use of the single cohort pilot design implemented by this study. There was no measurement of body fatigue (from heavy singing prior to recording, physical fatigue or inadequate sleep) or degree of stress. These variables may have influenced lung function measures, however, this may not have been indicated in the present pilot study as there were significant increases in FEV_1/FVC and FEV_1accompanied by moderate to large effect sizes (0.65 and 0.98 respectively). Further studies in this area to validate the above results are required. Future studies should include a control group and a larger sample size.

Ventilatory muscle training has also been shown to have beneficial effects on patients with COPD[8,9]. VFEs as an adjunct to COPD programs may provide an alternate method for therapy in this patient population. It may provide added compliance and enjoyment to individuals undertaking lung function training for COPD. Further research is required to substantiate the efficacy of VFEs as a method of treatment in all pulmonary patient groups.

CONCLUSION

VFEs combining isotonic and isometric exercises were shown to have beneficial effects on some aspects of the lung function of trained female singers. This was reflected in significant increases in FEV_1 and FEV_1/FVC. The improvement in lung function is supported by increases in vocal function reported in previous studies[2,3]. VFEs may benefit not only vocalist but also patients with various voice or pulmonary disorders and may be a useful adjunct to traditional therapy.

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Table 1:

Means and SD for FVC, FEV1 and FVC/FEV1 obtained during pre- and posttests

	Pre	Post	Cohen's d
FVC	3.33± 0.56	3.35±0.47	0.20
FEV1	2.65±0.65	2.88±0.42 $^{+}$	0.98
FEV1/FVC	79.59±12.70	85.44±3.63 *	0.65

+ Significant at $p < 0.05$; * Significant at $p < 0.01$.