Inspiratory Muscle Training in Three Athletes with Exercise-Induced PVFM
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Paradoxical vocal fold motion (PVFM) is a laryngeal disorder where abnormal vocal fold adduction interferes with normal respiration. Recent interest in PVFM has yielded numerous articles addressing the challenges of describing, classifying, differentially diagnosing, and managing this disorder. In exercise-induced PVFM, dyspneic episodes may be triggered by sports competition, practice, or any strenuous activity.

Many athletes with exercise-induced PVFM report that they limit their physical activity in an effort to minimize the frequency and severity of PVFM episodes. When the athlete does engage in increased physical activity, thereby eliciting PVFM symptoms, a maladaptive pattern emerges—the individual shifts into tense, shallow breathing with excessive tension and struggle focused at the laryngeal level. The perceived dyspnea contributes to additional struggle behavior.

The significance of ventilatory muscle fitness and the effectiveness of ventilatory muscle training have been demonstrated in patients with compromised respiratory function, in healthy sedentary individuals, and in trained athletes. In numerous published studies, inspiratory muscle training (IMT) increased inspiratory muscle strength and decreased perception of exertional dyspnea. Recently, inspiratory muscle training (IMT) involving inspiratory pressure threshold breathing maneuvers, resulted in decreased PVFM symptoms in a soccer player (Mathers-Schmidt & Brilla, in press) and rower (Ruddy, et al., 2004). The findings suggest that IMT benefits exercise-induced PVFM patients, where abnormal vocal fold adduction results in increased upper airway resistive load.

- The purpose of this study was to determine if inspiratory muscle training would result in increased inspiratory muscle strength, reduced perception of exertional dyspnea, and improved measures of maximal exercise effort in three young female athletes diagnosed with exercise-induced PVFM.

METHOD

Participants
- Three healthy, non-smoking females
  - Participant A (16:7 yo)
    History of acute dyspnea triggered by sprinting when playing soccer
  - Participant H (16:4 yo)
    History of acute dyspnea at high levels of exertion during swimming/running
  - Participant J (17 yo)
    History of acute dyspnea during X-country and track
    History of asthma and seasonal allergic rhinitis, well-managed with medications
- Careful differential diagnosis process supported a diagnosis of exercise-induced PVFM.
  Spirometry revealed truncated inspiratory flow volume loops. Transnasal flexible laryngoscopic evaluation after strenuous exercise revealed moderate PVFM during inhalation. First author confirmed that the participants’ histories and symptoms were consistent with exercise-induced PVFM.
  - Human Subjects Review Committee of WWU approved the study; study was explained to the participants and written informed consent was obtained.

Study Design
- ABAB within-subject withdrawal design
- 16 weeks:
  - Baseline data (week one)—maximum inspiratory pressure (MIP) x 3; dyspnea rating during trigger level of activity x 3; maximum exercise measure (WAnT, a 30-second Wingate anaerobic test); maximum voluntary ventilation (MVV, used as an independent measure of lung function).
  - Treatment and withdrawal phases (five weeks each)
    - Above measurements were completed at end of each phase; MIP and dyspnea ratings also completed at end of third week of each treatment phase
  - Prior to IMT, participants were educated regarding mechanics of respiration; they were also trained regarding optimal and relaxed-throat breathing
  - Two SLP graduate students made the MIP measurements and conducted IMT training sessions
  - Inter-trainer reliability: repeated determination of MIP varied by only 0-3%
Outcome Measures

• **Ventilatory Muscle Strength:** MIP was measured at the mouth using a mouthpiece with a two-way valve connected via a vacuum hose to the electronics of the IMT device; scaled output displayed on Fluke True-rms Multimeter, using min-max function. The experimenter instructed the participant by referring to a standard written MIP procedure adapted from Kellerman and colleagues. Maximum inspiratory pressure (MIP) measurements were repeated until three were obtained within 5% variability; largest MIP value was recorded.

• **Exertional Dyspnea:** Rated during trigger level of activity (sprinting). 4-point rating scale (0=no dyspnea, 1=mild, 2=moderate, 3=severe dyspnea).

• **Maximum Exercise Measure:** Wingate Anaerobic Power Test measured peak anaerobic power and mean anaerobic power during an all out 30-second cycle ergometer test. Subjects performed the test on a Monark 818 E ergometer, after 5-minute warm-up on a cycle ergometer. Graduate students in the Exercise Science program conducted this testing.

Inspiratory Muscle Training

• Custom-made inspiratory muscle strengthening device, modeled after device described by Sapienza and colleagues: mouthpiece and a solenoid valve that opens when sensor detects negative (inspiratory) pressure exceeding a threshold level. Valve remains open for exhalation.

• Participants trained 5 days per week for 5 weeks, according to a protocol adapted from Kellerman and colleagues.

• IMT session: 5 sets of 12 training breaths at designated threshold level. One minute rest period between sets. Each session approximately 30 minutes.

• IMT threshold levels based on MIP measurements; hence, threshold levels were adjusted according to MIP findings at baseline, end of third week of first training phase, beginning of second training phase, and end of third week of second training phase.

• Introductory training sessions—trained two days at 25% MIP; two days at 50% MIP.

• Remaining IMT sessions—trained at 75% MIP.

**RESULTS**

• **Ventilatory Muscle Strength:** MIP increased substantially across both IMT treatment phases. Little to no change in MIP occurred during the no treatment period. (Note: Participant J was ill at end of third week of second treatment phase.)
RESULTS (cont.)

- **Exertional Dyspnea:** Participant dyspnea ratings during research-based activity (sprinting at trigger level) did not change. Once participants were coached to maintain lab-based optimal breathing behaviors, dyspnea ratings decreased to "0" (no dyspnea). Participants reported a progressive decrease in frequency and severity of PVFM in nonresearch-based sports activities as IMT progressed; no PVFM symptoms in their respective sports activities by the end of the study, and at three month follow-up.

- **Maximum Voluntary Ventilation:** MVV increased throughout the study for each participant.

- **Maximum Exercise Measure:** (Peak power in watts—baseline, end of first treatment period, withdrawal, end of second treatment period) Participant A: 384,409,443,303; Participant H: 444,358,358,179; Participant J: 525,573,573,573 (Data are suspect due to procedural problems.)

- **Post-IMT Laryngeal Status:** Participants A and H had normal laryngeal examination findings, with no evidence of PVFM. Participant J reportedly had minimal vocal fold adduction on inhalation and exhalation. She also showed minimal erythema suggestive of reflux.

- **3 Month Follow-Up Report**
  - **Participant A:** No PVFM episodes since treatment period. Participating in soccer 2/wk and track 5/wk.
  - **Participant H:** No PVFM episodes since treatment period. Participated in tennis spring quarter and continues to workout 3-4 days per week doing 35 min. cardio and some weights.
  - **Participant J:** No PVFM episodes since treatment period. “I qualified for District in the 800 meter race today! My breathing is officially fixed. I, along with my coaches, am so excited to see what this will mean for next year’s cross country season. Thank you, thank you, thank you!”

DISCUSSION AND CONCLUSIONS

- Inspiratory muscle training was associated with increased measures of maximum inspiratory pressure across both treatment phases.
- During research session exercise at PVFM trigger level, patient ratings of dyspnea decreased only after participants were coached in maintaining optimal respiratory behaviors that had been used in the IMT laboratory setting.
- Participant ratings of exertional dyspnea may not be a valid measure of IMT efficacy. This outcome measure warrants careful consideration in terms of establishing procedural validity.
- Participant J’s peak performance data were similar to those of college students in a larger group study where IMT resulted in improved measures of peak power following 6 weeks of training at 75% MIP (Brilla, Victor, & Mathers-Schmidt, 2005). Other performance measures such as skills-specific tests may be necessary to validate IMT as a treatment approach for PVFM.
- By the end of the study, and at three month follow-up, participants reported no PVFM episodes during high level exertion in their respective sports.
- **These findings suggest that IMT may be a promising treatment approach, in conjunction with optimal breathing coaching, for athletes with exercise-induced PVFM.**
SELECTED REFERENCES


