A PRIMER ON INSPIRATORY MUSCLE TRAINERS
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Introduction
Inspiratory muscle training (IMT) has been described in the literature since the early 1980s [1]. Various IMT devices are available on the market and recent evidence suggests that outcomes vary depending on the type of device used. Commercially available inspiratory muscle trainers are relatively small, simple, single-patient use devices. Once taught, the patient can use the device independently in various settings and the progression of intensity can be readily calculated.

The purpose of IMT is to improve inspiratory muscle strength and endurance, thereby having a potentially positive effect on symptoms, exercise capacity and health-related quality of life outcomes for people with chronic respiratory diseases. Although IMT with the appropriate type of device can be beneficial, it is not considered a standard component of a pulmonary rehabilitation programme or treatment regimen [2, 3]. What follows is a simple guide to IMT – the types of device available; their clinical utility; application with different patient populations; and training considerations when prescribing IMT with patients. This information will assist you in including IMT in your practice.

What types of inspiratory muscle trainers are there?
There are three types or categories of inspiratory muscle trainer:

- nontargeted inspiratory resistance trainers;
- targeted inspiratory resistive or threshold trainers; and
- normocapnic hyperventilation trainers.

Let’s talk first about nontargeted inspiratory resistive trainers. As the name suggests, these devices don’t provide a target or means of controlling the patient’s breathing pattern. Without either of these features, it isn’t possible to ensure the patient attains the necessary training intensity. The most common commercial nontargeted devices are the PFlex and the IMT by DHD.

The PFlex is a small device with a mouthpiece and a circular dial. Turning the dial varies the size of the aperture through which the patient is to breathe. The smaller the aperture, the greater the intended resistance on inspiration. Respironics HealthScan Inc. (Cedar Grove, NJ, USA) distributes the PFlex.

The other nontargeted device is available from DHD (Canastota, NY, USA), this device includes six attachments, each with a different sized hole. The attachment is placed in-line (see white disc in situ in figure 1) and again is intended to vary the degree of resistance provided to the patient.

The second category of IMT is targeted inspiratory resistive or threshold trainers.
Targeted inspiratory resistive trainers provide a target intensity for the patient to strive towards. Threshold trainers control the intensity of inspiratory pressure. The necessary training intensity can be attained and maintained unless the person significantly alters his or her breathing pattern.

As the name suggests, targeted inspiratory resistive trainers (fig. 1) provide visual feedback to pace the breathing pattern. An adjustable resistance is placed in-line at the mouthpiece. The simplest and most common way to achieve this is to use an incentive spirometer to provide the target combined with a nontargeted inspiratory resistive trainer for adjusting the resistance. The person ultimately controls the pressure intensity of inspiration, however; if he or she achieves a target flow, the training pressure intensity will be achieved.

The Threshold® trainer is a small handheld device (fig. 2) supplied by Respironics. It includes a mouthpiece and a calibrated spring-loaded valve. The valve controls a constant inspiratory pressure training load and the patient must generate the inspiratory pressure in order for the inspiratory valve to open and allow inhalation of air. The valve is calibrated and can be adjusted according to a percentage of the patient’s maximum inspiratory pressure ($P_{I,max}$).

Up to this point, all four of the devices discussed above (nontargeted, targeted inspiratory resistive and threshold trainers) are relatively portable, handheld devices designed for single-patient use. Each manufacturer provides cleaning instructions.

The last type of IMT device is a normocapnic hyperventilation trainer. The apparatus provides a visual target and uses a rebreathing system with oxygen infusion to maintain constant levels of arterial CO₂ and O₂. The training intensity is set at a percentage of the patient’s maximum voluntary ventilation. This type of device can be cumbersome, requiring more equipment than the other inspiratory muscle trainers mentioned above. It has primarily been used in research and at present is not readily available to clinicians.

**What are the pros and cons of the devices?**

Given that nontargeted resistive trainers don’t ensure a consistent training intensity and that the normocapnic hyperventilation trainers are not presently practical in the clinical setting, IMT is best achieved using the targeted inspiratory resistive or threshold trainers.

There are pros and cons to consider when choosing whether to use a targeted inspiratory resistive or threshold trainer. Hsiao et al. [4] compared the two types of device in a randomised control trial. From the patient point of view, the visual feedback with the targeted type of device gave positive feedback and so improved patients’ motivation to inspire against the resistance, while the Threshold® trainer was hard to keep clean and dry in the high humidity of Taiwan. From the clinician point of view, it was difficult to measure whether patients were exercising at their proper intensity when using the targeted trainer, but the Threshold® trainer provided a consistent training intensity with intensities $>9$ cmH₂O.

Two other factors to consider when choosing a trainer are related to the way the resistance is generated with the targeted and Threshold® devices [5]. With targeted devices, the patient can breathe in whether or not he or she achieves the target level. There is a short ramping up and down of the intensity pressure with each breath. For the...
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Threshold® trainer, training intensity is preset on the device. The patient must generate enough force to match this intensity so that the valve will open to allow inspiration. This results in a square waveform with each breath. Depending on the patient’s abilities, one of these may be less or more suited.

Why use an inspiratory muscle trainer: what is the evidence?

Individuals with chronic respiratory disease, including asthma, cystic fibrosis and chronic obstructive pulmonary disease (COPD), may experience inspiratory muscle dysfunction for many reasons, such as altered respiratory mechanics, increased work of breathing, malnutrition, hypoxia, deconditioning and long-term steroid use [3, 6, 7]. As a result, these individuals may present with shortness of breath and decreased exercise tolerance. In response, patients may self-limit their activities, resulting in a further increase in their sensation of dyspnoea and reduction in their exercise tolerance and quality of life.

The muscles of inspiration, however, are like other skeletal muscles: they can adapt in response to exercise when challenged with a sufficient load. RAMÍREZ-SARMIENTO et al. [8] demonstrated that IMT improves inspiratory muscle strength and endurance and causes structural changes in the muscle fibres. Improving inspiratory muscle strength and endurance is a management strategy that is meaningful to patients when it translates into less dyspnoea. When less short of breath, patients are able to increase their level of activity and improve their health-related quality of life.

The use of IMT has been examined in asthma, cystic fibrosis and COPD with mixed results. In a Cochrane Collaboration systematic review that investigated the effect of IMT with asthma, RAM et al. [9] identified five articles for inclusion, four of which were by WEINER and colleagues [10–13]. The participants in these studies were defined as having stable asthma. P_{\text{I,max}} was used as a measure of inspiratory muscle strength, but a measure of inspiratory muscle endurance was not included. RAM et al. found that P_{\text{I,max}} significantly improved by a mean of 23 cmH2O in persons with asthma. All three papers included in this meta-analysis for P_{\text{I,max}} used the threshold type of IMT device and had a total of 76 participants. There was not enough evidence to determine whether any clinical benefits were associated with the improved P_{\text{I,max}}.

We are in the process of completing a systematic review investigating the effect of IMT in individuals with cystic fibrosis. Only two studies met the inclusion criteria. In the study that used the threshold trainer [14], inspiratory muscle endurance (% P_{\text{I,max}} sustained for 1 min) significantly increased from 49 to 66% P_{\text{I,max}}, while inspiratory muscle strength only showed a trend towards improvement. However, measures of exercise capacity, shortness of breath or fatigue were not significantly changed. The other study [15] compared high- and low-intensity IMT to a control group. The device used was more suitable to the research environment given its cost and technological design. Results showed significant increases in inspiratory muscle strength among participants using IMT at high intensity (80% of maximal effort).

The evidence for the use of IMT in adults with stable COPD is much more extensive and conclusive. In our systematic review, we stratified the research based on the type of device and the comparison groups [1]. The three types of device described above (targeted inspiratory resistive or threshold trainers; nontargeted inspiratory trainers)
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resistance trainers; and normocapnic hyperventilation trainers) were outlined this review. Several comparison groups were included in the review but those of relevance here were a) targeted inspiratory resistive or threshold IMT versus no intervention or versus sham IMT; and b) non-targeted inspiratory resistive IMT versus sham IMT.

Meta-analyses comparing targeted inspiratory resistive or threshold IMT versus sham showed significant overall effect in favor of the IMT for measures of inspiratory muscle strength ($P_{I,max}$ mean increased by 12.3 cmH$_2$O) and endurance (inspiratory threshold loading mean increased by 1.0 kPa), Borg score for respiratory effort (mean decreased by 2.3 points), work rate maximum (mean improved by 13.8 W) and dyspnoea (transition dyspnoea index mean improved by 3.4 points). The meta-analysis included 34 participants for Borg scale to 233 participants for inspiratory muscle strength outcomes. One study [16] demonstrated a clinically important change in the Chronic Respiratory Disease Questionnaire, bearing in mind that a “change of 1.0 reflects a moderate change, and difference of 1.5 represents a large change” [17].

In summary, targeted inspiratory resistive or threshold IMT for individuals with stable COPD significantly improves some outcomes of inspiratory muscle strength, inspiratory muscle endurance and exercise capacity, and decreases shortness of breath. The clinical benefits of threshold IMT for individuals with asthma or cystic fibrosis, however, have not yet been demonstrated.

Where and on whom can IMT be used?

Adults with stable COPD are the patient population most suited to targeted inspiratory resistive or threshold IMT. IMT may be a component of a patient’s pulmonary rehabilitation programme. However, it can also be used as a stand-alone intervention where training of the limbs may be risky (e.g. severe dyspnoea, angina) or where a general exercise programme cannot be supervised adequately.

Healthcare professionals with expertise in exercise training and in the respiratory system are best able to implement IMT. This would include physical therapists, respiratory therapists and respirologists. They are also the professionals to most likely be involved in a pulmonary rehabilitation programme.

Given that IMT is intended for people with stable COPD and that the devices are portable and easy to use, targeted inspiratory resistive or threshold trainers can be used in the outpatient or home setting. If your rehabilitation programme offers an inpatient option, IMT would also be appropriate. However, IMT may be inappropriate for use for inpatients in an acute exacerbation of their COPD.

How should IMT be used?

When prescribing IMT, the clinician must take into account several
factors to minimise patient risk and ensure patient safety. They include the patient’s comorbidities, motivation, level of dyspnoea and severity of disease as well as the training parameters needed to improve inspiratory muscle strength and endurance.

The training protocol should include the mode, frequency, intensity and duration.

**What signs and symptoms should I watch for to avoid injury or risk to the patient?**

It is important to implement a training protocol that balances benefits against possible risk for the patient. Benefits will be achieved by ensuring an adequate training protocol. Careful monitoring of the patient to avoid fatigue of or injury to the inspiratory muscles will minimise risks. Unfortunately, obvious clinical indications of fatigue or injury, such as discordant chest wall movement or rising arterial CO₂ levels, may not be apparent until the patient is substantially compromised. Table 2 offers suggestions of clinical parameters to monitor.

**How do I know the patient is getting stronger: what clinically relevant outcome measures should I use?**

Given the intended benefits of IMT, the following outcome measures are suggested.

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<table>
<thead>
<tr>
<th>Training parameter</th>
<th>Definition</th>
<th>Recommendations [1, 5]</th>
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<tbody>
<tr>
<td><strong>Mode</strong></td>
<td>Type of IMT</td>
<td>Targeted inspiratory resistive trainer or threshold-type trainer.</td>
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| **Frequency**      | a. Number of training sessions per day  
                      | b. Number of days per week | a. 1–2 training sessions per day, depending on patient exercise capacity.  
                      |                           | b. 4–6 days of training sessions per week according to patient tolerance. |
| **Intensity**      | Load against which the person is exercising | Percentage of P₁max is the most common method for setting the intensity. A range of 30–70% P₁max is described in the literature. A lower initial intensity is recommended for people with severe COPD.  
                      |                           | Progression: up to 5% per week of P₁max as tolerated.  
                      |                           | Retesting: P₁max should be measured at least monthly and training intensity adjusted accordingly. |
| **Duration**       | a. Length of each training session  
                      | b. Number of weeks of training | a. Total of 30 min per day (divided over 1–2 sessions). However, sessions may initially need to be as short as 3–5 min.  
                      |                           | b. Continue indefinitely to maintain training benefits. Functional improvement and adaptive structural changes can occur after 5 weeks of training. Most training benefits are lost after 6 months without training. |

Table 1. Recommended training protocol for inspiratory muscle training.
Inspiratory muscle strength.

The most frequently used measure of inspiratory muscle strength is $P_{I,max}$.

Inspiratory muscle endurance.

There are several possible measures to choose from for inspiratory muscle endurance. They include sustained time on the inspiratory training device, incremental threshold loading, maximum sustained ventilatory capacity or maximal sustainable inspiratory mouth pressure. Clinically, the sustained time on the inspiratory training device is the simplest to implement as it uses the trainer the person is training on [5].

Dyspnoea.

The Borg scale is a common, easily used self-report measure for dyspnoea. It should be used to measure the person’s overall shortness of breath and the level experienced during activity or exercise. Other measures cited in the literature on IMT are the baseline dyspnoea index and the transition dyspnoea index. They are interviewer-administered scales.

Exercise capacity.

Various measures of exercise capacity have been used in IMT. Our systematic review found no significant overall effect on maximal oxygen consumption or the 12-minute walk test, while there was a significant effect in favour of work-rate maximum and the Borg scale for respiratory effort (modified Borg scale) [1]. However, other recent studies have reported a significant improvement in the 6-minute walk test [18, 19]. Given its ease of administration and that it has been validated in persons with COPD, the 6-minute walk test may be the most effective and clinically applicable outcome [5].

Health-related quality of life.

Both the Chronic Respiratory Disease Questionnaire and the St. George’s Questionnaire have been validated in people with COPD and used as outcomes in IMT.

Closing thoughts

IMT is an easy to use, low-cost intervention that can result in improved outcomes when you
select the appropriate device, use an appropriate training protocol and choose the patients best suited to its use. Devices are readily available at present and perhaps in the future a commercially viable normocapnic hyperventilation trainer will become available, increasing consumer choice. So what is the problem? IMT is not considered to be a standard component of a pulmonary rehabilitation programme or treatment regimen. Healthcare providers need to take up the challenge to make it a part of routine care for people with chronic respiratory disease.

Acknowledgements

Figure 1 and table 2 are reprinted, with permission, from Reid WD, Geddes EL, Crowe J. Inspiratory muscle training in COPD. Physiotherapy Can 2004; 56: 128–142.

FURTHER READING